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THE INDIAN JOURNAL OF ENTOMOLOGY

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Agricultural Gardens,
Kanpur.

K. B. LAL,
Chief Editor,
Indian Journal of Entomology.

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The Indian Journal of Entomology

Vol. IX, Part I

June 1947

OBSERVATIONS ON THE LIFE-CYCLE OF A CHALCID PARASITE *TETRASTICHUS COCCINELLAE* KURDJ.

By D. J. W. RANAWEERA

Tea Research Institute of Ceylon, St. Coombs, Talawakelle

(Communicated by Dr. K. B. Lal)

Larvae of the lady-bird beetle, *Chilomenes sexmaculata* Fabr., which feed on aphids infesting *Tephrosia vogelii* at St. Coombs, Talawakelle, were found to be heavily parasitised by a Chalcid parasite of the genus *Tetrastichus*. Through the courtesy of the Director and Entomologist of the Department of Agriculture, Ceylon, I have been able to compare my specimens with others collected from pupae of Coccinellae and determined by Ferrière as *T. coccinellae* Kurdjumov, and am satisfied that my specimens are identical with this species.

Kurdjumov (1913) described *T. coccinellae* as a parasite on *Coccinella septempunctata* Linn. It has since been reported by Bogunova and Telenga (1939) as the most important parasite of two Coccinellids (*Chilocorus renipustulatus* Scriba. and *C. bipustulatus* Linn.) predatory on the San José scale in the Caucasus.

The presence of this parasite of Coccinellids in Ceylon suggests its distribution to be wider than the literature indicates. As the original description is probably not available to many students, I give below a description of the Ceylon specimens. For the study of the life-cycle, the host *Chilomenes sexmaculata* was bred in the laboratory to ensure freedom from previous parasitisation.

Tetrastichus coccinellae Kurdj.

♀ *Body* shining black with bluish reflections. Antennae dark brown. Legs black except the tarsi and the tibiae which are yellow. Wings hyaline; stigma and veins dark brown.

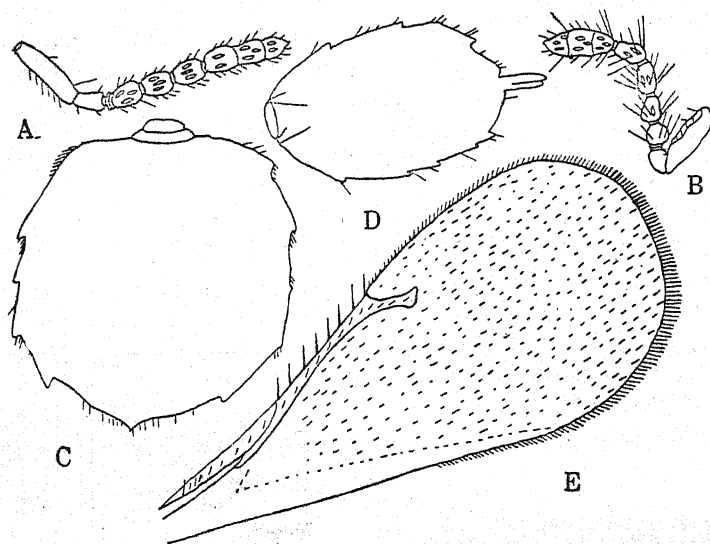


FIG. 1. *Tetrastichus coccinellae* Kurdj.—A. ♀ antenna. B. ♂ antenna.
C. ♀ abdomen. D. ♂ abdomen. E. ♀ forewing.

Head transverse, about one and a half times as broad as long, sparsely hairy and slightly punctate; ocelli forming a low triangle, the lateral ocelli as near to the eye margin as to each other. Antennal furrow broad and shallow. Eyes almost circular, naked; cheeks as long as the transverse breadth of an eye, crossed by a furrow which stretches from the base of the eye to the mandible. Antennae inserted a little below the middle of the face; scape short, just reaching to the front ocellus, slightly broader in the middle; pedicel, a little shorter than half the length of the scape and a little longer than broad; 2 very small annelli; 3 funicle joints, almost quadrate, subequal in length and little longer than the pedicel; club with three joints, a little longer than the two preceding joints together, the last joint shorter and conical; all joints covered with short ciliae.

Thorax smooth and shining, very finely shagreened. Mesonotum with deep parapsidal furrows, the median furrow very short but distinct; scutellum shorter than the mesonotum, very convex with two thin longitudinal furrows; propodeum finely rugulose with a median carina and two lateral carinae. Wings large reaching beyond the tip of the abdomen, hyaline, rounded at the apex, with long marginal ciliae about twice as long as the discal ciliae which are numerous, short and irregularly placed except for a long row above the lower margin; submarginal vein with a single bristle, twice as long as the discal ciliae; marginal vein little longer than the submarginal, thickened at the base and bearing a row of 8 or 9 long bristles about one and a half times as long as that on the submarginal vein. Costal cell with a row of 6 or 7 short ciliae similar to the discal ciliae.

Stigmal vein about one-third the length of the marginal vein broadening towards the end; post marginal vein absent. Hind wings narrow and relatively short. Legs, thin, normal.

Abdomen almost circular, about as broad as the thorax, and slightly longer than broad, ending obtusely, bearing a few short hairs.

♂ smaller, with the following differences:

Antennae brown except for the funicle joints which are yellow. 1st funicle joint shorter than the 3 others; all funicle joints and the 1st club joint bear a circlet of long ciliae each longer than the joint itself; a few shorter hairs are present near the apices of all joints except the club which is more densely covered; club broader than the funicle joints; sensorial organ on the scape narrow and elongate. Abdomen narrower, about one and a half times longer than broad. After death the aedeagus often protrudes from the tip of the abdomen.

Measurements.—♀ 1.23 to 1.53 mm. Average 1.40 mm.

♂ 0.9 to 1.2 mm. Average 1.06 mm.

Ceylon, Talawakelle. May 1948. Tea Research Institute of Ceylon. No. 580.

Host.—*Chilomenes sexmaculata*.

Chilomenes sexmaculata normally lays its eggs on leaves, but in the insectary she deposits them, usually in clumps of 5 to 10, almost anywhere, on glass, or cotton wool, but rarely on cut leaves in the cage. The eggs hatch after 3 days. The larval stage occupies 8 to 10 days, during which time there are 3 moults. The pupal stage lasts 4 to 6 days. In the insectary the larvae are cannibalistic and are best kept separately. The female beetles also will devour their own eggs.

The parasite *T. coccinellae* attacks *Chilomenes* larvae of all ages, by first lodging on their backs. The larva attempts to dislodge her, usually without success, by running or by jerking its body. When about to lay an egg the parasite first lowers its ovipositor into position and, with a quick downward movement of the abdomen, thrusts it to its full extent into the larva. If the larva is stationary when attacked, it usually begins to run rapidly. The parasite, however, sits undisturbed with its wings folded along the body and antennae held forward motionless, and she remains in that position with ovipositor inserted for two minutes or more. After withdrawing the ovipositor, if the larva has stopped running, she moves backwards until her head is over the wound she has made and then feeds on the exuding body fluid. She never turns round to reach the wound and sometimes she does not attempt to feed, particularly if the larva is still running. At times she appears to be prevented from feeding by the quick jerky movement of the larva's body. When feeding she may remain with her head over the wound for as long as two minutes. A larva which has previously been parasitised is less active when attacked again and will often continue

feeding on aphids. On these insects a parasite is usually more successful in obtaining a meal.

The parasite appears indifferent as to in what part of the host's body she inserts her ovipositor. If there is any preference, it is for places between segments of the thorax or abdomen, but the sting is often inserted into segments and in one instance it was seen to enter the head before the capsule had hardened after moulting. The parasite will sometimes take an interest in a cast skin before perceiving her error. She has not been observed to attack pupae.

Usually one egg is left in the body with each thrust of the ovipositor but sometimes two or more are probably laid. For instance, one larva was stabbed 9 times within $1\frac{1}{2}$ hours and was later found to contain 20 parasite larvae. Another was stabbed 8 times in $2\frac{1}{2}$ hours; later, 15 parasites were obtained from it. These host larvae were reared in the laboratory and protected both before and after the experiment. More usually the number of parasites obtained on dissection is equal to or less than the number of stabs observed. As the parasite sometimes keeps her ovipositor within the host for as long as five minutes it is possible that more than one egg is deposited at such times. No evidence of polyembryony has been obtained.

Superparasitism is very common and it is not unusual to obtain 10 or 12 parasites from naturally infested hosts collected from the field. The largest number obtained from one Coccinellid larva was 18. In the laboratory a larva may be attacked many times by the same or by different females. Mention has already been made of the observation that the parasite is rarely able to feed at the wound made when the first egg is laid, and the question arises whether the desire for a meal stimulates the parasite to make further attacks on the same host, as insect juices probably form an important part of her diet. Females have been observed to prick lightly the host's body with the ovipositor without thrusting it sufficiently deep for oviposition, but the parasite has not been observed to feed at such places. In the open, a fast running larva has a better chance of escape from the parasite after she has alighted from its back and there is less chance for her to attack it again almost immediately, as is possible in small observation cages in the laboratory. Hunger may act as an extra stimulus to oviposition and so lead to marked superparasitism when hosts are scarce.

The sting does not cause any degree of temporary paralysis and parasitised larvae appear to behave exactly as healthy larvae. They feed normally until in due course they pupate.

Development.—Although several Coccinellid larvae have been dissected shortly after being parasitised the newly laid eggs have not been found. Eggs have been found in the body fluid three days after parasitisation. They are then oval, translucent, smooth, with a very thin chorion without sculpture, and measure $0.16-0.24 \times 0.24$ mm. Such eggs are almost due to hatch, as the incubation period is usually 4 days.

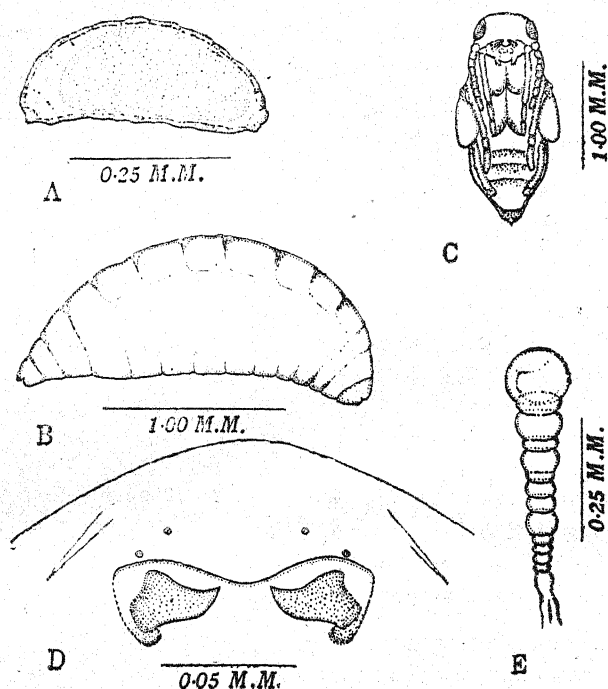


FIG. 2. *Tetrastichus coccinellae* Kurdj.—A. 1st instar larva. B. Full grown larva. C. Pupa. D. Mandibles of full grown larva. E. Spiracle of full grown larva.

First instar larvae are white, except the area from the metathorax to the 8th abdominal segment which is creamy yellow. The body is elongate oval, tapering slightly towards the caudal end. It has 13 segments but no spiracles, and measures $0.25-0.48 \times 0.15-0.19$ mm. The skin is smooth without cuticular structures. Head distinct with curved mandibles, 12.4μ long. The first moult occurs after one or two days.

Second instar larvae are similar but larger, measuring $1.03-1.10 \times 0.34-0.45$ mm. and have 9 pairs of spiracles, one in the mesothorax and the others in each of the first eight abdominal segments. The mandibles are somewhat stouter and measure 23.5μ in length. The second stadium lasts about 3 days.

Third instar larvae are darker yellow in colour and carry the head bent downwards. The segments are more clearly defined and the tracheal system is better developed. They measure $1.41-1.45 \times 0.50-0.55$ mm. and the mandibles are $31-33 \mu$ long. This instar lasts 4 days.

Fourth instar larvae are dark yellow except for the first 3 and last segments which are paler. They measure $1.61-2.15 \times 0.64-0.80$ mm. and the mandibles are heavily chitinised, $35-37 \mu$ long. This stadium lasts about 2 days.

A prepupal stage lasts one day. The body is differentiated into 3 distinct regions. In size it is very similar to 4th instar but the colour is paler.

The host (*Chilomenes*) always pupates before the parasite. The egg and larval stages of the parasite together occupy 14 to 15 days which is longer than the larval life of the host. Whether the lady-bird larva is parasitised while very young or just before pupation makes little or no difference to the rate of development of the parasites. In no instance have parasite pupae been found within larval hosts.

The parasite pupa measures $1.23-2.30 \times 0.54-0.70$ mm. At first it is white with antennae, eyes, mouth appendages, leg and wing rudiments, thoracic and abdominal segments clearly defined. As the pupa ages, the colour changes gradually to dark brown. The head and thorax darken first and the abdomen later. A day before emergence the whole insect becomes black. There is no cocoon. The pupal stage occupies 10 days.

The emergence of the parasites from their pupal cases has not been seen but dissections disclose that they are free within the beetle pupal case for two days before escaping. Then, a neat circular hole is cut in its dorsum through which the parasites emerge. When several parasites are within the host two circular emergence holes are sometimes cut, but most frequently one only is made.

Females will oviposit during the first day of their adult life. Whether mating occurs before emergence is not known though it has been observed later. Adult females have been maintained in the insectary for 32 days.

ACKNOWLEDGEMENT

I have pleasure in tendering my thanks to Dr. C. H. Gadd for his helpful advice and criticism and for assistance with the manuscript. His constant encouragement and watchful interest throughout the progress of this work are gratefully acknowledged. I am also greatly indebted to Mr. W. T. Fonseka for the drawings of the immature stages of the parasite.

SUMMARY

Tetrastichus coccinellae is described and an account of its life-history in its host *Chilomenes sexmaculata* is given.

The life-cycle occupies 25-26 days made up of the following stages:—egg 4 days; larva 10-11 days; prepupa 1 day; pupa 10 days. The adults leave the host pupa two days later.

The economic value of the lady-bird *Chilomenes* is materially reduced by the attack of this parasite.

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- KURDJUMOV, N. V., 1913, *Rev. Russe Ent.*, St. Petersburg, 13 (1): 27-43 (*Rev. app. Ent.*, (A), 1: 456-458).
BOGUNOVA, M. V. AND TELENGA, N. A., 1939, *Rev. app. Ent.*, (A), 27: 303-304.

THREE NEW SPECIES OF *TETRASTICHUS*

By D. J. W. RANAWEEERA

Tea Research Institute of Ceylon, St. Coombs, Talawakelle

(Communicated by Dr. K. B. Lal)

Parasites and hyperparasites of the genus *Tetrastichus* were encountered while studying the insect pests of tea. Examination of the collections made during the last few years reveals that none can be referred to any known species described from India or Ceylon and listed by Mani (1938). Although collections have been obtained from several different hosts, only three distinct species have been encountered.

The first for which I propose the name *Tetrastichus versicolor* is the commonest and is very variable in colour. Typically the specimens are metallic blue with greenish reflections. Some specimens from the same and similar hosts show no greenish reflections (Var. A) and others are metallic green with no blue coloration (Var. B). No collection, however, contains more than one variety. Apart from their colour these varieties are indistinguishable. There is, however, a third variety with darker legs and wing venation, brown instead of yellow, and with 15-17 bristles on the marginal vein instead of the more typical 12-15. Although this variety has been collected twice, females only have been seen. For the present and until the male characters are known it seems inadvisable to regard these insects as of a different species because of these small differences.

The females of the second species, *T. taprobanensis*, at first sight closely resemble those of *T. versicolor*, but the males are easily distinguishable by antennal characters. Closer examination of the females however reveals a shorter (relative to length of head and thorax) and less pointed abdomen, a larger number of bristles (7-9 as compared with 3-5 of *T. versicolor*) on the submarginal vein and a deeper, broader furrow in the mesonotum.

The third species *T. niger* is black but is readily distinguishable from *T. coccinellae* Kurdjumov, 1912, by the shorter marginal ciliae of the wings and the almost obliterated median furrow. Like *T. coccinellae* this species appears to be a primary parasite.

Tetrastichus versicolor sp.n.

♀ ♂ *Body* colour variable, typically metallic blue with greenish reflections, finely shagreened. Legs pale yellow except for coxae and femora which are concolourous with thorax.

♀ *Head* transverse, finely punctate with a few fine short hairs. Ocelli in an almost straight line surrounded by a deep groove; the lateral ocelli nearer to the eye margin than their own diameter, and joined to the eye margin by a thin

furrow; cheeks as long as the eye diameter, crossed by a furrow running from the base of the eye to the mandible, smooth, with a few scattered shallow punctures and short bristles. Antennal furrow broad and shallow. Eyes almost circular. Antennae inserted below the middle of the face; scape testaceous, short, reaching scarcely to the front ocellus; other joints dark brown; pedicel a little shorter than half the length of the scape; 2 annelli, the first very small; 3 funicle joints subequal in length, the first a little longer than either the second or third which are of approximately equal length; all broader than and about twice as long as pedicel; club with 3 joints, narrow and elongate, almost as long as the two preceding joints together; all joints covered with short ciliae.

Thorax.—Rounded, longer than broad with a row of short hairs along the posterior margin of the pronotum which is finely aciculated. Mesonotum large, finely reticulate, with a row of short hairs along each parapsidal furrow, median sulcus faint; parapsidal furrows large and deep; scutellum finely reticulate, shorter than the mesonotum, very convex, with deep longitudinal furrows. Propodeon finely granulated, with a median carina and lateral carinae.

Wings large, reaching beyond the tip of the abdomen, rounded at the end with long marginal ciliae; discal ciliae short, about half the length of the marginal ciliae, numerous and irregularly placed except for a distinct row just above the lower margin. Submarginal vein with three to five bristles on the

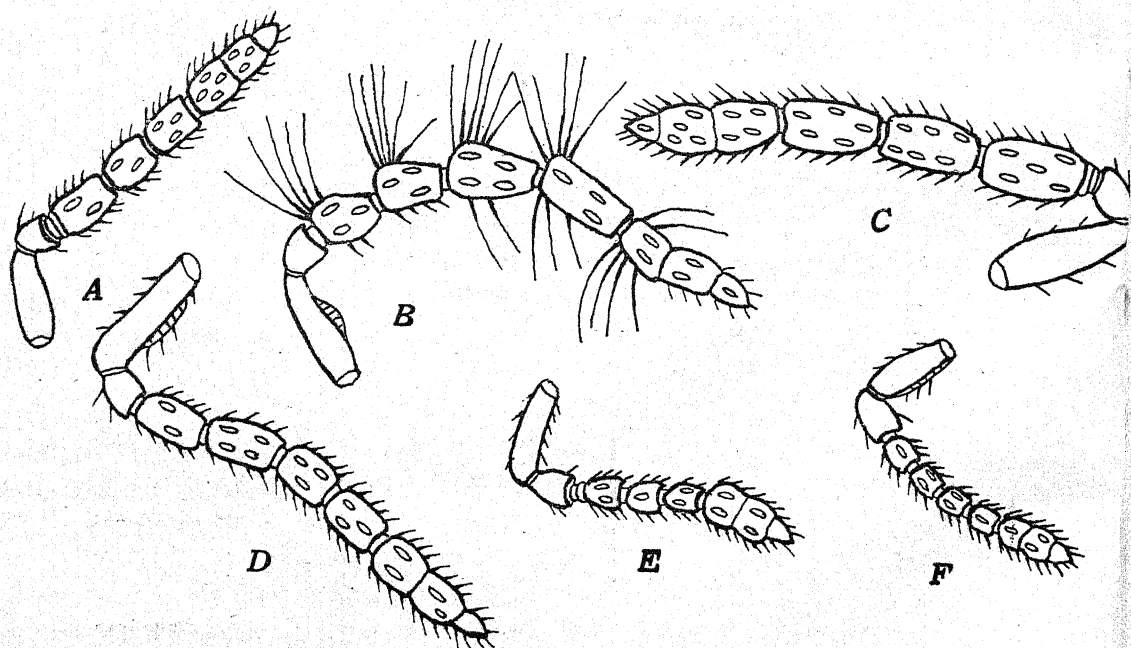


FIG. 1. Antennae.—A. *Tetrastichus versicolor* ♀; B. ♂; C. *T. taprobanensis* ♀; D. ♂; E. *T. niger* ♀; F. ♂.

upper side; marginal vein narrow, longer than the submarginal vein, bearing a row of 12 to 15 long bristles little longer than those on the submarginal vein and about 3 times the length of the discal ciliae; stigmal vein narrow, almost one-third the length of the marginal vein, broadening towards the end. Legs normal. *Abdomen* broadened at the middle, gradually narrowing to an acute apex, sparsely hairy, a little longer than the head and thorax together, not broader than the thorax, ovipositor not protruding. Tip of the abdomen brown.

♂ Similar, smaller, whole antennae brown, first funicle joint little longer than the pedicel, shorter than the 3 others. Club 3 jointed, shorter than the two preceding joints together, all funicle joints and the 1st club joint bear at the base clumps of ciliae longer than the funicle joints. Sensorial organ on the scape small and oval. Abdomen oval, little shorter than the thorax. Length ♀ 1.7-2.2 mm.; ♂ 1.5-1.7 mm.

Ceylon, Talawakelle, February 1933. Tea Research Institute of Ceylon, No. H. 35.

Hosts.—Hyperparasite on *Elasmus homonae* Ferr. and *Macrocentrus homonae* Nixon., both *ex Homona coffearia* Niltz. on tea plant.

Holotype, one female; Allotype one male, both on cards. Paratypes, several males and females on cards; antennae and abdomens of males and females and female wings mounted on slides.

Variety A.—♀ ♂ Blue but without greenish reflections. Otherwise as type. Length ♀ 1.7-2.2 mm.; ♂ 1.5 mm.

Ceylon, Talawakelle, July 1931. *ex Notolophus posticus* Walk. on Dadap. T.R.I. No. H. 8; hyperparasite on *Elasmus homonae ex Homona coffearia* on tea. T.R.I. No. H. 23, February 1934; hyperparasite on *Phytodietus capuae* Morley *ex Homona coffearia* on tea. T.R.I. No. H. 108, Ceylon, Madulsima, November 1937; hyperparasite on a parasite on *Homona coffearia* on tea, T.R.I. No. H. 136.

Holotype, one female; Allotype one male, both on cards. Paratypes, several males and females on cards and mounted on slides.

Variety B.—♀ Green, legs yellow except the coxae which are dark brown. Otherwise similar to type.

Length ♀ 1.6-2.3 mm.

Ceylon, Talawakelle, March 1936. Hyperparasite on *Apanteles taragamae* Vier. *ex* a Lasiocampid caterpillar. T.R.I. No. H. 97.

Holotype, one female on card. Paratypes several females on cards and mounted on slides.

Variety C.—♀ Blue. Legs brown except for coxae and femora which are blue. Marginal and submarginal veins darker than type. Marginal vein with 15 to 17 bristles. Otherwise similar to type.

Length ♀ 2.0-2.7 mm.

Ceylon, Talawakelle, February 1935. Hyperparasite on *Goniozus montanus* Kieff. ex *Homona coffearia* on tea. T.R.I. No. H. 71. Hyperparasite on *Phytodietus capuae* ex *Homona coffearia* on tea. T.R.I. No. H. 72.

Holotype, one female on card. Paratypes, one female on card and two females mounted on slides.

Tetrastichus taprobanensis sp.n.

♀ ♂ Body metallic blue with greenish reflections, shageened. Legs pale cream except for coxae and major part of femora which are concolourous with thorax.

♀ Head shiny, broader than deep, about as broad as thorax, face green, deeply punctate with fine short hairs; vertex broad. Ocelli placed in an almost

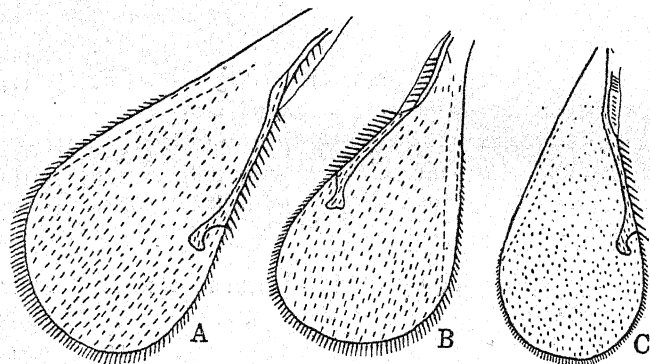


FIG. 2. Forewings.—A. *T. versicolor* ♀; B. *T. taprobanensis* ♀; C. *T. niger* ♂.

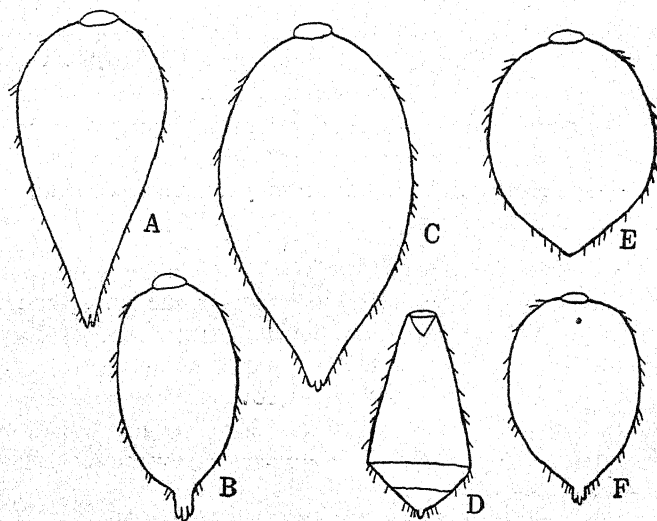


FIG. 3. Abdomens.—A. *Tetrastichus versicolor* ♀; B. ♂; C. *T. taprobanensis* ♀; D. ♂; E. *T. niger* ♀; F. ♂.

straight line, surrounded by a groove which extends laterally to the eye margins. Lateral ocelli nearer to the eye margin than their own diameter. Eyes oval, large, naked. Cheeks almost as long as the eye diameter, shiny, green, finely striate, with a few short hairs and a few scattered shallow punctures; a deep furrow runs from the base of the eye to the mandible. Antennal furrow broad and deep. Antennae inserted a little below the middle of the face. Scrobes oval. Scape yellow brown, long, reaching the front ocellus; pedicel yellow brown; funicle joints and club fuscous. Scape more than twice as long as broad; pedicel little less than half the length of the scape; 2 annelli, funicle joints sub-equal in length and breadth; 1st funicle joint little more than twice as long as the pedicel, almost twice as long as broad, 2nd equal to 1st; club with three joints, as long as the pedicel and the 1st funicle joint together. All joints covered with short ciliae.

Thorax.—Large, longer than broad. Pronotum rounded with irregular aciculations and a few scattered short hairs. Mesonotum large, finely reticulate, shiny with a row of hairs near the inner margin of each parapsidal furrow. Median and parapsidal furrows deep and large. Scutellum nearly as long as the mesonotum, finely reticulate, very convex, with deep longitudinal furrows slightly converging posteriorly. Propodeum more than half as long as the scutellum, finely rugulose with short irregular ridges and well-developed median and lateral carinae. Spiracles small and oval.

Wings reaching beyond the tip of the abdomen, broadly rounded at the end. Marginal ciliae little longer than the discal ciliae except those on the lower margin which are about twice as long. Discal ciliae short and not densely placed, with a regular row near the lower margin of the wing. Submarginal vein has on its lower side a single bristle about, or a little more than, twice the length of the discal ciliae, and a row of 7 to 9 short bristles on the upper side. Marginal vein about twice as long as the submarginal vein with a row of 12 to 15 long bristles as long as the single bristle on the lower side of the submarginal vein. Stigmal vein about one-third the length of the marginal vein, thin at the base, thickened at the end. Legs slender. *Abdomen* shiny, conical oval, pointed behind, sparsely hairy, almost as long as the head and thorax together; ovipositor slightly protruding.

♂ Similar, smaller. Antennae more elongate. Scape about three times as long as broad; pedicel about one-third the length of the scape, and half as long as the 1st funicle joint. All the four funicle joints twice as long as broad, sub-equal in length. Club as long as the two preceding joints together, 3 jointed, elongated and pointed at the end. All joints covered with short ciliae. Sensorial organ on the scape elongated covering about half the length of the joint. Femora of 1st and 2nd pair of legs dusky. Abdomen narrower and rounded at the posterior end, shorter than the thorax.

Length ♀ 1.92–2.64 mm. ♂ 1.56–2.0 mm.

Ceylon, Passara, April 1944. No. 216.

Host.—*Natada nararia* Mo. on tea.

Holotype, one female; Allotype, one male, both on cards. Paratypes, several males and females on cards, antennae and abdomens of males and females, and female wings mounted on slides.

Tetrastichus niger sp.n.

♀ ♂ *Body* shining black, shagreened; antennae dark brown with yellow brown scape and pedicel; legs testaceous except for coxae and femora which are dark brown.

♀ *Head* transverse, shining black, sparsely hairy, punctate; ocelli forming a low triangle, not surrounded by a groove; lateral ocelli as far from each other as from the eye-margin; cheeks smooth, shining, as long as the transverse diameter of an eye, crossed by a faint furrow running from the base of the eye to the mandible. Antennal furrow narrow. Eyes naked, black, almost circular. Antennae inserted below the middle of the face; scape short, not reaching the front ocellus; pedicel longer than broad, about half the length of the scape; 2 annelli; 3 funicle joints sub-equal in length and each longer than the pedicel. Club 3 jointed, broader than the funicle joints and longer than the two preceding joints together, the last joint shorter and conical; funicle and club covered with short ciliae.

Thorax shiny, very finely shagreened. Pronotum broad, finely aciculated, with a row of hairs along the posterior margin and a few scattered ones below. Mesonotum reticulate, with two deep parapsidal furrows, each bearing a row of short hairs; median furrow very weak, nearly obliterated anteriorly; scutellum finely reticulate shorter than the mesonotum, convex, with two longitudinal furrows. Propodeon short, rough, shagreened, with a median carina and two lateral carinae.

Wings large, reaching beyond the tip of the abdomen, hyaline, broadly rounded at the apex, with short marginal ciliae about the same length as the discal ciliae which are numerous and irregularly placed, except for a distinct row just above the lower margin; submarginal vein with 3 to 5 small bristles; marginal vein narrow, longer than the submarginal vein with a row of 12 to 13 long bristles about one and a half times the length of those on the submarginal vein; stigmal vein narrow, about one-third of the marginal vein, broadening towards the end; costal cell with a row of 7 to 8 ciliae similar in size to discal ciliae and about half the length of the bristles on the submarginal vein. *Abdomen* sparsely hairy, circular, as long as the thorax, ending obtusely; ovipositor not protruding.

♂ Similar but slightly smaller, and with narrower antennae; funicle joints 4, subequal in length, longer than broad and slightly shorter than the pedicel; club as broad as the funicle joints, and longer than the two preceding joints

together; funicle and club covered with short ciliae. Sensorial organ on the scape, narrow and elongate, almost as long as the scape itself. Legs normal. Abdomen narrow, a little longer than broad, slightly narrower and shorter than thorax. Aedeagus often protruding from the tip of the abdomen after death.

Length ♀ 1.4-1.7 mm. ♂ 1.0-1.3 mm.

Ceylon, Passara, September 1935. T.R.I. No. H. 78.

Host.—*Simplicia robustalis* Guen. on tea.

Holotype, one female; Allotype one male, both on cards. Paratypes, several males and females on cards, antennae and abdomens of males and females, and female wings mounted on slides.

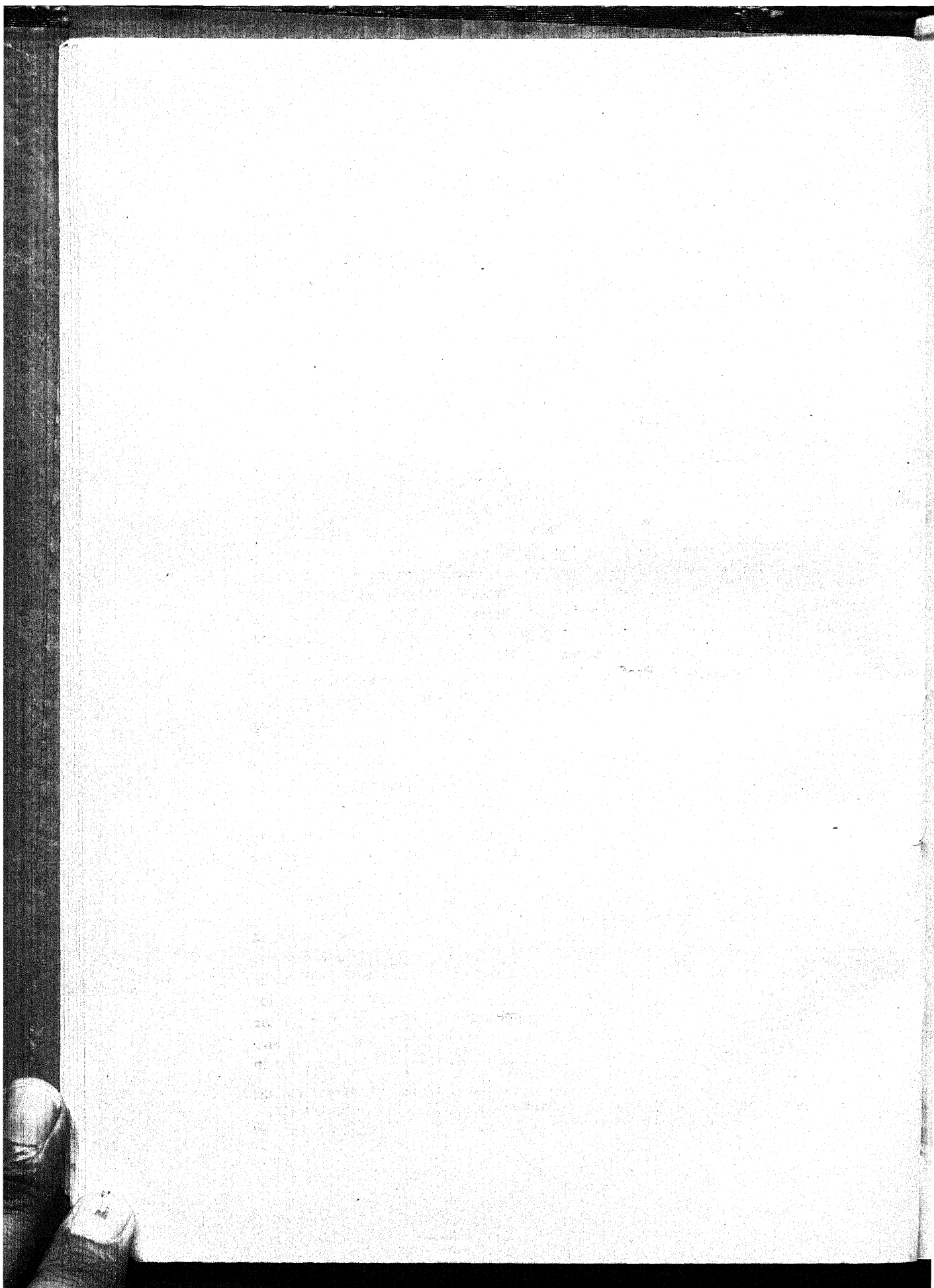
Holotypes and Allotypes of all the three species have been deposited in the National Pusa Collection, Indian Agricultural Research Institute, New Delhi.

ACKNOWLEDGEMENT

Grateful thanks are due to Dr. C. H. Gadd who by helpful criticism, constant encouragement and assistance with the manuscript has contributed much to this work.

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A NEW SPECIES OF MEALY BUG FROM INDIA*

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I. INTRODUCTION

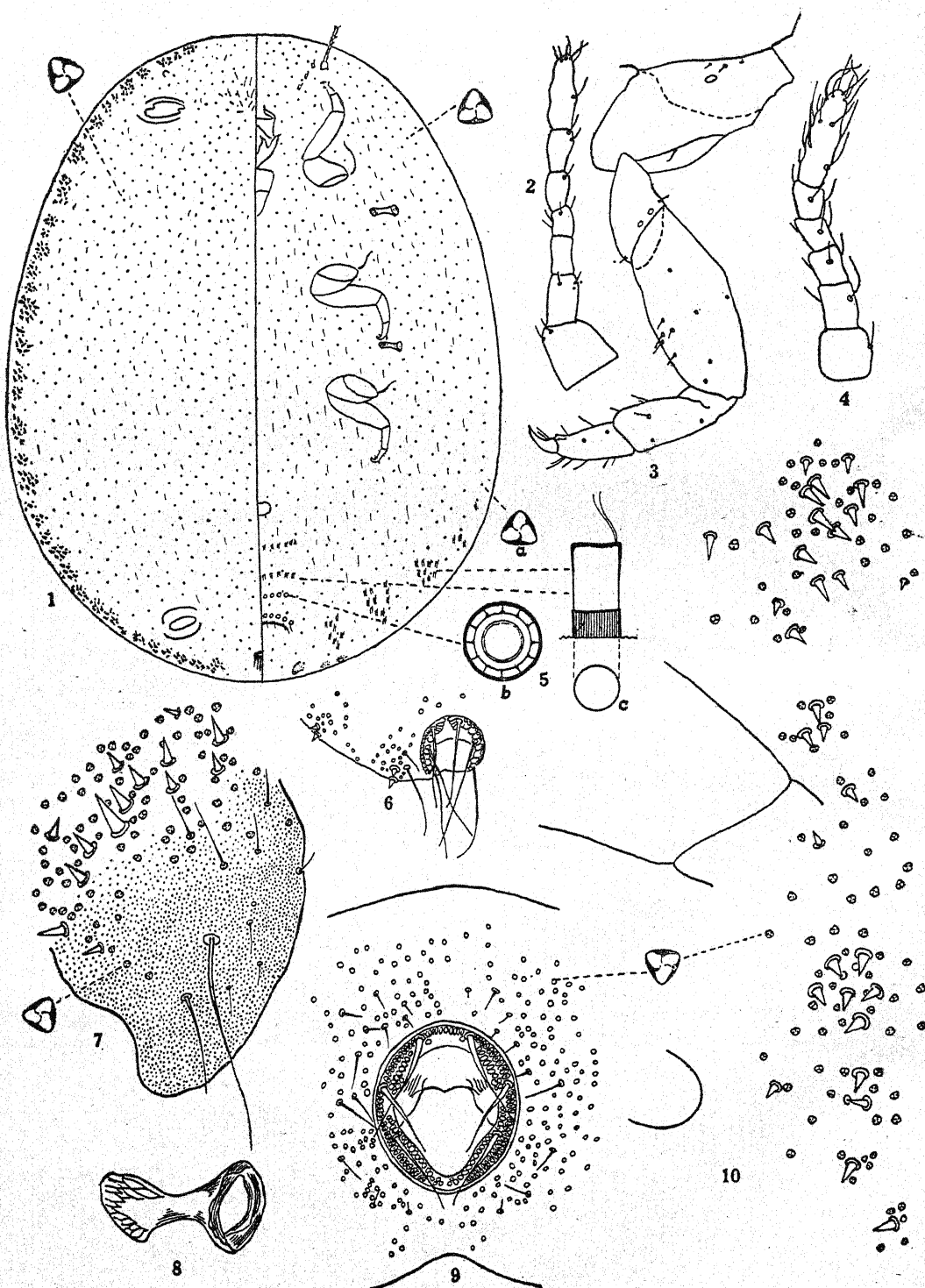
This species of mealy bug was first received for identification some years ago from the Head of the Division of Entomology, Indian Agricultural Research Institute, New Delhi, having been received by him in turn from the Forest Entomologist, Dehra Dun. The material which was collected by one Mr. Sharma was found to be badly attacked by fungus and the exact identification could not therefore be made. More material was received some time later which unfortunately also proved to be in the same condition. The author's visit to Assam in 1945 in connection with a survey of the fluted scale enabled him to examine Dibrugarh area and collect fresh specimens of the insect from the very plantation from which specimens had been collected twice before including once by Mr. Sharma. During his visit to the United States recently the author was able to identify the species with the help of Prof. G. F. Ferris of Stanford University, and Dr. Harold Morrison of the Bureau of Entomology and Quarantine, U.S. Department of Agriculture. Prof. Ferris is of opinion that species allied to this mealy bug have probably been thrown by various coccidologists under the genera *Farinococcus*, *Formicococcus*, *Lachnodi*, *Lachnodiella*, *Pseudococcus* and *Ripersia*. It may take some time therefore for all the species to be re-examined, their exact position determined and the genera reviewed. Meanwhile, at the suggestion of Dr. Harold Morrison, this species has provisionally been included in the genus *Paraputo* with whose characters it best agrees.

The author takes this opportunity to express his great indebtedness to Dr. Harold Morrison and Prof. Ferris for their help and co-operation in the preparation of this paper.

II. *Paraputo taraktogeni* sp. nov.

Female.—Hemispherical, covered with a white mealy wax secretion. Antenna seven segmented (Fig. 2). Legs short and stout; tarsal and ungual digitules present (Fig. 3). Spiracles large (Fig. 8). Dorsum and ventrum with large number of ceres with three partitions projecting from the margin to the interior (Figs. 1 and 5a). These pores, a little more numerous on the dorsum than on the ventrum. A few pointed setae found scattered on the dorsum and the ventrum, those on the ventrum longer and larger in number. Multilocular pores present in

* This paper was prepared for publication at Stanford University, California, and the Bureau of Entomology and Quarantine, U.S. Department of Agriculture, Washington D.C.

*Paraputo taraktogeni* sp. nov.

EXPLANATION OF FIGURES

1. General dorsal and ventral views of the whole adult female, showing the important parts of the body and the position of structures of taxonomic importance.
2. Antenna of adult female.
3. Leg of adult female.
4. Antenna of larva.
5. (a) Triangular pore as seen from top.
(b) Multilocular circular pore as seen from the top.
(c) Side view of tubular duct.
6. Posterior portion of larva showing the anal ring and two cerarial tracts.
7. Last cerarial tract of adult female.
8. Anterior spiracle of adult female.
9. Anal ring region of adult female.
10. Anterior cerarial tracts of adult female.

the genital region (Fig. 5b). Cerarial tracts innumerable, not clearly separated from each other, varying in size and in the number of the setae (Fig. 10). Areas below the last three cerarial tracts slightly sclerotised. In the region of the five posterior-most cerarial tracts near the margin and towards the ventrum, a few ducts present. Two or three similar ducts also present in the anterior region on the ventrum on the inner side of antenna. Some of these ducts a little smaller in size than the others. A few similar smaller-sized ducts also present on the ventrum, in the segments posterior to the circulus and anterior to the genital opening. Dorsal ostioles well developed. Circulus present, rectangular with rounded corners (Fig. 1). Anal ring with six setae, one pair slightly longer than the other two (Fig. 9). Anal lobe with a number of setae one of which is very long (Fig. 7).

This is an ovoviviparous species. Fully developed larvae have been noticed inside the body of gravid females. This condition has made it possible to study the taxonomic characters of the larva.

Larva.—Antenna six segmented (Fig. 4). Anal ring with six setae. The cerarial tracts with a pair of setae each. Two caudal setae one longer than the other present near the last cerarial tract (Fig. 6).

Holotype.—A female specimen on slide in the Coccid collection of the Directorate of Plant Protection, Quarantines and Storage, New Delhi.

Paratype.—Several females as dry specimens in the Coccid collection of the Directorate of Plant Protection, Quarantine and Storage, New Delhi. A few specimens in the U.S. National Collection of Coccidae, Washington D.C.

This species is a serious pest of *Taraktogzenos kurtzii* in the plantation belonging to the Forest Department of Assam, near Dibrugarh. The mealy bug attacks the roots of the host plants. As the valuable *chalmogra* oil is extracted from the host plant, the record and identification of this pest is of importance.

Relationships.—The author has had the opportunity to examine slides of *Paraputo multispinosus* James (1935) and *Lachnodiella acritocera* Chaffin (1923) available in the U.S. National Collection of Coccidae and of *Paraputo ritchei* Laing (1929) in the British Museum. *Paraputo taraktogeni* resembles *P. ritchei* and *P. multispinosus* but can be separated from them by the presence of cerarial setal clusters on all segments. The sclerotisation below the last three tracts which is seen in *taraktogeni* is absent in *ritchei* as well as in *multispinosus*. The number of antennal segments are six in these species while they are seven in *taraktogeni*. According to Strickland (1947), *P. multispinosus* is a synonym of *P. ritchei*. *Paraputo taraktogeni* resembles very greatly the species described as *Lachnodiella acritocera* Chaffin but can be distinguished from it by the smaller number of lateral ducts in the last three segments, the smaller number of antennal segments and the presence of sclerotisation below the last three cerarial tracts. In the opinion of the author if *taraktogeni* is to be included under *Paraputo*, *Lachnodiella acritocera* Chaffin has also to be included in that genus.

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STUDIES ON THE SOMATIC MUSCULATURE OF THE DESERT LOCUST, *SCHISTOCERCA GREGARIA* (FORSKÅL) PHASE *GREGARIA*

PART III. THE PTEROTHORAX

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I. INTRODUCTION

In Parts 1 and 2 of this series (Misra, 1945, 1946), I had described the musculature of the head-capsule, neck and prothorax of the Desert Locust, *Schistocerca gregaria* (Forskål), phase *gregaria*. The present part deals similarly with the pterothorax (meso- and meta-thorax) of the same phase. The serial numbers of the muscles are continued from Part II.

As in previous parts, I have compared the muscles of the Desert Locust with those of other Acridiidae, viz., *Anacridium aegyptium* Linn. (Berlese, 1909; La Greca, 1947); *Doclostaurus maroccanus* Thunb. (Jannone, 1940) and *Dissosteira carolina* (Snodgrass, 1929). Of these, the account of *A. aegyptium* is rather fragmentary, and in the case of *D. maroccanus*, Jannone has not given a description of muscles of the wings, and of the basipodite (coxa) and telopodite of the metathoracic legs. A critical comparison of the skeletal parts has been made with Karandikar's (1939, 1945) descriptions of the Desert Locust.

The comparative study of the wingless prothorax and the wing-bearing meso- and meta-thorax in relation to their musculature provides a good analysis of

these regions and is helpful in clarifying the basic uniformity and symmetry of structures in the three regions. Wherever any modifications are found to have occurred, they have been correlated with the special functions that the region concerned performs. This explains many points such as the following: (i) The compactness and complicated nature of the mesonotum are correlated with the articulations of the tegmina which are also compact as compared to the wings. (ii) The greater length of the metanotum, as compared to mesonotum, is correlated with greater expanse of the wings. (iii) The drastic reduction of intersegmental membrane between the pleura and the sterna of the meso- and meta-thorax are meant to provide immovable and firm footholds for the muscles of flight in the pterothorax so that no muscular energy is wasted in moving the parts themselves on which the muscles arise. (iv) The progressive width of the basicoxa, from procoxa to metacoxa, is meant to provide for extra and stouter muscles of legs which have gone over to the service of the tegmina and the wings. This comparative study also helps one to interpret the homologies of the various sclerites of the meso- and meta-sternum in terms of the generalized plan for insects (Snodgrass, 1935).

As before, I have given measurements of the muscles to give a rough idea of their dimensions. They are not to be utilized for comparison of phase and other types of variations.

This work was carried out while holding the Junior Research Fellowship of the National Institute of Sciences of India, in the Department of Zoology under Professor K. N. Bahl's guidance. I am grateful to Professor Bahl and to Dr. M. L. Roonwal for critically going through the manuscript and suggesting many improvements from time to time, and to Dr. S. L. Hora for kindly providing me library facilities at the Zoological Survey of India at Banaras and Calcutta. I am also thankful to Md. Kazim Naqvi for much assistance with regard to the illustrations.

II. SKELETAL PARTS

1. Tergal (Notal) Region

(a) MESONOTUM (Figs. 1, A-D and 4, A-P)

The *mesonotum* is more compact and complicated than the pronotum due to its articulations with the tegmina (elytra). It consists of a single segmental plate connected with the pronotum through a large anterior intersegmental membrane (*i.m.*). It is strengthened by 5 transverse dorsal sutures and the corresponding ventral ridges; these appear to be mechanical devices to bear the strain exerted on the mesonotum by the vigorous activity of the tegmina. On the basis of these sutures the plate may be divided into 5 regions, *viz.*, (i) the precosta (*pc.*; pretergite of Karandikar, 1939); (ii) the ventral antecosta, phragmata and the prealar arm; (iii) the prescutum; (iv) the scutum; and (v) the scutellum with its lateral lobes, and the post-scutellum (post-tergite of Karandikar, 1939).

The *precosta* (*pc.*) is the narrow, sclerotized posterior part of anterior inter-segmental membrane which has become secondarily incorporated into the mesonotum.

The *antecostal suture** (*acs.*) lies immediately behind the *precosta*, marks the original anterior limit of the mesonotum and appears ventrally as a prominent ridge, the *antecosta* (*a.c.*). The latter gives off antero-laterally 2 partly hollowed plates, the *phragmata* (1 *ph.*), and beyond them, on either side, a process called the *prealar arm* (*pa.*) which supports the mesonotum on the pleuron.

The *prescutum* (*ps.*) constitutes the antero-lateral part of the mesonotum and forms an irregular plate. It is marked off from the rest of the mesonotum by an oblique *prescutal suture* (*ps.s.*) which runs backward and outward from the antecostal suture. It is divided into 2 parts, the proximal and distal, by the curved *intra-prescutal suture* on the dorsal surface and its ridge on the ventral surface. The proximal part (*p.ps.*) is depressed, the deepest part of the depression lying distally; the intra-prescutal ridge gives out two apodemes—a small anterior (*a.ap.*) one and a large posterior (*p.ap.*) one—which give insertion to a part of the first tergo-sternal (85) and the entire tergo-pleural dorsal muscles (90) respectively. The distal part, which is convex and obliquely disposed, has two notches along its external border, one vertical and another horizontal (excavations of the suralar process of Karandikar, 1939). The vertical notch accommodates the condyle of the costo-subcostal sclerite (*C.Sc.s.*) of the tegmen, while the horizontal notch, lying immediately behind, provides a socket for the curved anterior process of the first axillary sclerite (*vide infra*). The distal part is attached externally to the first basalar mesepipleurite (Fig. 1 B, 1b. *mep.*) through a membrane, and posteriorly to the preaxial border of the tegmen through a short rounded sclerite (*tegula*, *tg.*) which is convex dorsally and concave ventrally.

From Karandikar's (1939, p. 30) description of the prescutum as "shoulder-like" and his Fig. 28 (marked as *PSC₂*) it appears that he has included in it only the distal part of the prescutum and omitted the proximal part, perhaps because of his failure to spot clearly the prescutal suture. He makes no mention of the intra-prescutal ridge and its apodemes. He regards the prealar arms as blunt processes of the prescutum, while in fact they are lateral extensions of the antecosta, for, they possess grooves similar to those of the antecostal suture.

The *scutum* (*sct.*) lies behind the antecostal and prescutal sutures and forms the greater part of the mesonotum. It is an octagonal, lid-like structure which bulges out into right and left lobes; medially it is slightly concave and slopes backward. Its posterior boundary is marked by the *scuto-scutellar* (*s.scl.s.*) and the *reversed notal sutures* (*r.n.s.*) and their corresponding ridges. The first suture and its ridge, according to Snodgrass (1935, p. 179), "are the most constant features of the wing-bearing plates and are present in some form in

* Snodgrass's (1929) term *antecostal suture* is preferable to Karandikar's (1939) *pretergal suture*, for, the suture actually belongs to the antecosta below and not to the pretergite (*precosta*) in front of it; the latter has been secondarily incorporated into the mesonotum from the inter-segmental membrane.

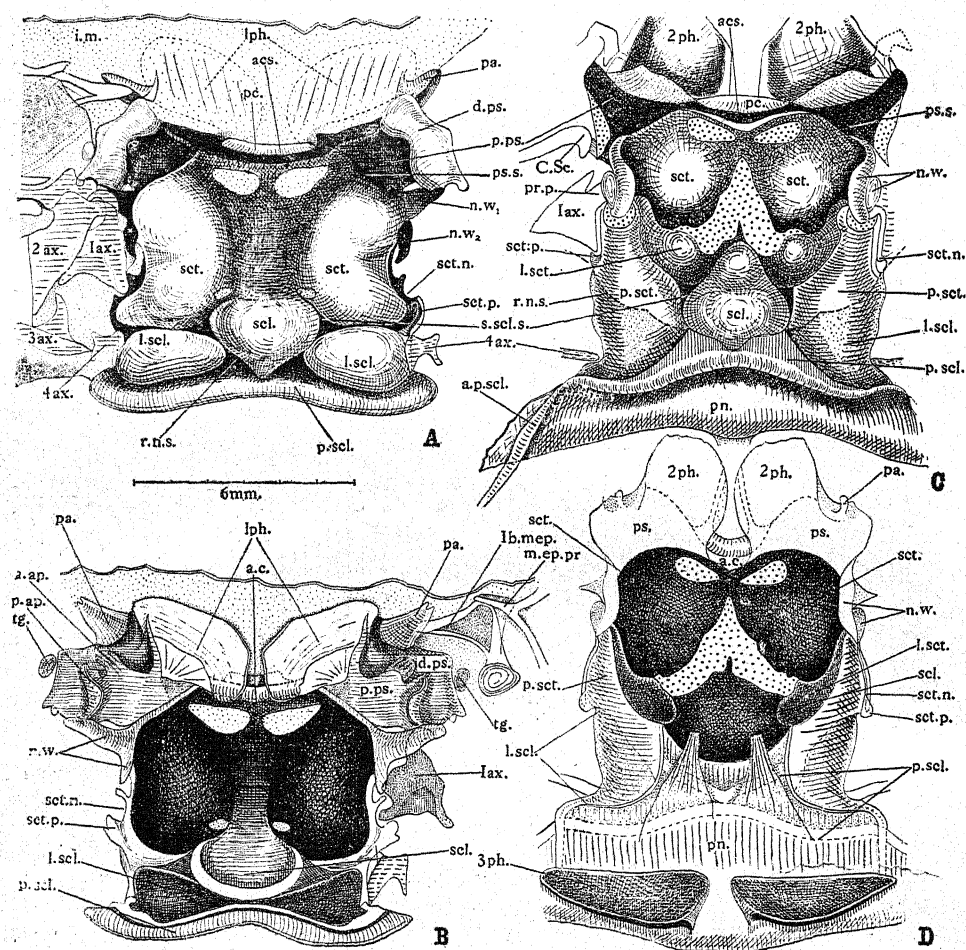


Fig. 1, A-D. *Schistocerca gregaria*, ph. *gregaria*.—A. Mesonotum, with the base of the left tegmen attached to it. Dorsal view. B. Same, with part of the base of left tegmen, first basalar mesepipleurite and a portion of dorsal mesopleuron. Ventral view. C. Metanotum, with the costo-subcostal vein and the first and fourth axillary sclerites of the left wing attached to it. The anterior phragmata have been cut away to expose other parts. Dorsal view. D. Same, in ventral view.

a.ap., anterior apodeme of prescutum; *a.c.*, antecosta; *acs.*, antecostal suture; *a.p.scl.*, arm of postscutellum; *1 ax.*, *2 ax.*, etc., first axillary sclerite, second axillary sclerite, etc.; *1 b.mep.*, first basalar mesepipleurite; *d.ps.*, distal part of prescutum; *i.m.*, intersegmental membrane; *l.scl.*, lateral scutellar lobes; *m.ep.pr.*, mesepisternal process; *n.w.*, *n.w.*, first and second prongs of notal wing-process (*n.w.*); *pa.*, prealar arm; *p.ap.*, posterior apodeme of prescutum; *pc.*, precosta of meso- and metanotum; *1 ph.*–*3 ph.*, phragmata; *pn.*, postnotum; *p.ps.*, proximal part of prescutum; *pr.p.*, proximal process of first axillary sclerite; *ps.*, prescutum of metanotum; *p.scl.*, postscutellum; *p.scl.*, prescutal suture; *r.n.s.*, reversed notal suture; *sct.*, scutum; *scl.*, scutellum; *sct.n.*, scutal notch; *sct.p.*, scutal process; *tg.*, tegula.

nearly all winged insects". He has described this suture in all winged insects as lying "in the posterior part of the alinotum [mesonotum] with its apex directed forward", and dividing "the notum into an anterior scutum and a posterior scutellum". In *Schistocerca gregaria* it is very much reduced and is broken up into 2 short brackets facing each other. The reversed notal suture is characteristic of the family Acridiidae and is similar in shape to the scuto-scutellar suture of the generalized insect, but has its apex directed backward instead of forward. At the places where the ridges of these 2 sutures intersect, lie triangular depressions (Fig. 1 B) which give insertion to the second oblique dorsal muscles of the tegmen (88). Each outer margin of the scutum is thickly cuticularized and is turned downward; anteriorly each margin gives rise to an anterior double-pronged *notal wing-process* (*n.w.*) whose anterior prong is at a lower level than the posterior one. The first axillary sclerite of the tegmen articulates between these prongs. Just behind the posterior prong occurs an emargination followed by a *scutal notch* (*sct.n.*); into the notch fits the posterior limb of the first axillary sclerite (Fig. 4 A-C, *p.p.*). Each lateral margin of the scutum behind the notch is produced into a blunt *scutal process* (*sct.p.*; Karandikar's posterior notal wing-process, 1939, p. 31), the outer part of which slopes downward and then turns upward. The scutum has 2 large, weakly cuticularized, triangular patches near its anterior margin and 2 similar but small, rounded patches near its posterior margin. The small patches indicate the places of insertion of the first oblique dorsal muscles (87); the large ones do not have any connection with muscles.

Karandikar (1939, p. 31) mentions a suture running "all along its (*i.e.*, of the scutellum) lateral and posterior margin", but has failed to realise that his suture is a part of the scuto-scutellar suture which, according to Snodgrass's (1935, p. 179) generalized plan, divides the mesonotum into an anterior scutum and a posterior scutellum. Similarly, the reversed notal suture, overlooked by Karandikar, explains the separation of the lateral scutellar lobes (*l.scl.*; his parascutellar lobes) from the scutellum. The 2 subpyriform, unchitinized areas "just behind the anterior margin of scutum, which indicate the site of muscle attachment internally" (Karandikar, 1939, p. 31) correspond to my 2 triangular patches (*vide supra*), but these have really no muscles attached on their under surfaces. The two dotted but unlabelled circles shown by Karandikar (his Fig. 28) in the scutellum correspond to my two rounded patches in the scutum showing places of insertion of the first pair of oblique dorsal muscles (87). He has missed the scutal notch altogether and has erroneously called the scutal process (*sct.p.*) as the "unforked posterior notal wing process". According to Snodgrass (1909; 1935, p. 183) the posterior notal, wing-process, "usually gives support to the third axillary sclerite of the wing-base, but sometimes a fourth axillary sclerite intervenes between the third and the notal margin, and in such cases a posterior wing-process is usually absent". Since in *Schistocerca gregaria* the scutal process does not support the third axillary sclerite, and a fourth axillary sclerite is present, a posterior notal wing-process must be taken as absent in this locust. This interpretation is borne out by the fact that the same sclerite is also wanting in the grasshopper, *Dissosteira carolina* (Snodgrass, 1929).

The *scutellum* (*scl.*) is a heart-shaped pouch lying medially behind the scutum and separated from it by the scuto-scutellar suture and from the lateral lobes of scutellum by the reversed notal suture. The *lateral scutellar lobes* (*l.scl.*) are a pair of ovoid pouches, one on either side of the scutellum. The outer

border of each lobe is thickly cuticularized and is bent downward and then upward to form an interlocking device for its articulation with the fourth axillary sclerite; posteriorly this border is fused with a stiff membrane at the base of the metanotal phragma of its own side. The *postscutellum** (*p.scl.*) has the form of a narrow band behind the scutellum and its lateral lobes; it is folded beneath itself all along its length and its posterior border bends again downward up to the posterior boundary of the scutellum and its lateral lobes where it becomes connected with a very much reduced intersegmental membrane between the mesonotum and the metanotum.

The lateral scutellar lobes (*l.scl.*) correspond to Crampton's (1918) and Karandikar's (1939) parascutellar lobes in *Dissosteira carolina* and *Schistocerca gregaria* respectively, and to Snodgrass's (1929, p. 39) lateral posterior scutal regions in *Dissosteira carolina*. Snodgrass, however, does not seem to be justified in assigning them to the scutum, since, according to his later interpretation (1935), the scuto-scutellar suture divides the notum into a scutum and a scutellum. The region of the mesonotum behind this suture must, therefore, be regarded as belonging to the scutellum and not to the scutum.

(h) METANOTUM (Figs. 1, A-D and 4, A-P)

The *metanotum* is a more delicately built and specialized plate than the mesonotum. It is also longer as it has to provide attachment for the larger wings. The metanotum consists of 6 sclerites, viz., (i) the precosta; (ii) a sclerite composed of the dorsal antecostal suture, the ventral antecosta, the anterior phragmata and the prealar arms; (iii) the prescutum; (iv) the scutum; (v) the scutellum and postscutellum; and (vi) the postnotum and the posterior phragmata.

The *precosta* (*pc.*) is shorter than in the mesonotum, and lies closely pressed beneath the posterior border of the mesonotal postscutellum thereby minimising movement between these 2 notal plates. On either side of it lies a stiff, weakly cuticularized membrane—the only remains of the intersegmental membrane at the antero-lateral boundary of the antecostal suture. This membrane is fused in front with the mesonotal lateral scutellar lobe and firmly connects the 2 notal plates.

The *antecostal suture* (*acs.*) is wider than the corresponding mesonotal suture and looks more or less like a groove. The *phragmata* (2 *ph.*) are stouter and larger, but the *prealar arms* (Fig. 1 D, *pa.*) are rudimentary. Each arm arises from the base of the phragma as a small, forwardly directed protuberance lying externally to the stiff membrane and attached to the inner limb of the fourth mesonotal axillary sclerite.

* Snodgrass's (1929) term *postscutellum* is preferable to Karandikar's *posttergite* for, the latter is likely to be confused with a structure homologous to the postnotal part of the metanotum. If Karandikar's term *posttergite* is to be understood as the posterior counterpart of the *pretergite*, it would mean a structure originally belonging to the intersegmental membrane and secondarily incorporated with the mesonotum (like the postnotum). Actually the postnotum, by virtue of its situation behind the scuto-scutellar suture, must be regarded as the posterior part of the scutellum.

The *prescutum* (*ps.*) is greatly reduced and lies behind the antecostal suture and in front of the prescutal suture. Its large proximal part is thick while the distal part (elaborate and well developed in the mesonotum) remains as an inconspicuous membranous strip; the intra-prescutal suture and its ridge, therefore, cannot be made out and there are no apodemes on its ventral surface corresponding to the anterior and posterior apodemes of the mesonotum. The prescutum is triangular and concave and is strongly cuticularized posteriorly for articulation with the base of the subcostal vein (*Sc.*) through a strong ligament, while in the corresponding mesonotal structure it is a notch in the distal piece of prescutum (*d.ps.*) which provides articulation for the subcostal vein of the tegmen.

The *scutum* (*sct.*) is weakly cuticularized and possesses 2 patches like those in the mesonotum, and an additional large, median and triangular patch. This median patch cuts the scutum more or less into right and left halves, which are less convex than in the mesonotum and consequently do not bulge. The *notal wing-process* (*n.w.*), unlike the stout and double pronged process of the mesonotum, consists of a single, strongly cuticularized and backwardly directed process having an elastic lobe with which is fused the first axillary sclerite of the wing, while the *scutal notch* (*sct.n.*) and the *scutal process* (*sct.p.*) are similar in situation and articulations to those of the corresponding mesonotal structures. On either side of the median line, behind the scutum and the median patch is situated a large, obliquely placed and convex *lateral scutal lobe* (*l.sct.*) which extends backward and inward from the thickly cuticularized outer scutal margin. Behind and outside each lateral scutal lobe lies a large piece sloping down externally; it is situated at a lower level and is divisible into an anterior thickly cuticularized and a posterior thinly cuticularized part. The line of demarcation between them may be regarded as representing a part of the *reverse notal suture* (*rn.s.*) extending immediately behind the scutellum, while the *scuto-scutellar suture* (*s.scl.s.*) runs along the inner borders of the 2 lateral scutal lobes and the entire antero-lateral margin of scutellum. Therefore, the anterior part of the large piece, lying within the range of the scuto-scutellar suture, may be called *post-scutum* (*p.sct.*), and the posterior part lying behind the reversed notal suture, the *lateral scutellum* (*l.scl.*). The latter has a small notch near its posterior outer border for the articulation of the fourth axillary sclerite.

Since the greater part of the scuto-scutellar suture is absent, there is some difficulty in determining the exact limits of the scutum. On the other hand, it is possible, with the help of the reversed notal suture, to separate the lateral pieces of the scutellum (*l.scl.*) from the postscutum.

The *scutellum* (*scl.*) lies behind the median membranous patch of the scutum. Its lateral divisions (*l.scl.*) are situated at a lower level and are much less cuticularized than the corresponding lateral scutellar lobes of the mesonotum. The *postscutellum* (*p.scl.*) resembles the corresponding sclerite of the mesonotum and is fused with the anterior boundary of the postnotum (*vide infra*). The

postscutellum gives off laterally a large, backwardly directed arm (*a.p.scl.*) crossing over the postnotum on either side and giving support to the base of the hind-wing.

The *postnotum* (*pn.*) is an additional plate in the metanotum which is formed by the sclerotization of the entire intersegmental membrane between the metanotal and the first abdominal tergal plates. It is a broad piece lying behind the postscutellum and situated at a lower level; anteriorly it becomes telescoped beneath the postscutellum and is fused with it, while laterally it extends downward beneath the arms of the postscutellum to be wedged into the *metepimeron* (Fig. 2, *mt.epm.*). Two large, tendon-like apodemes are given off from the

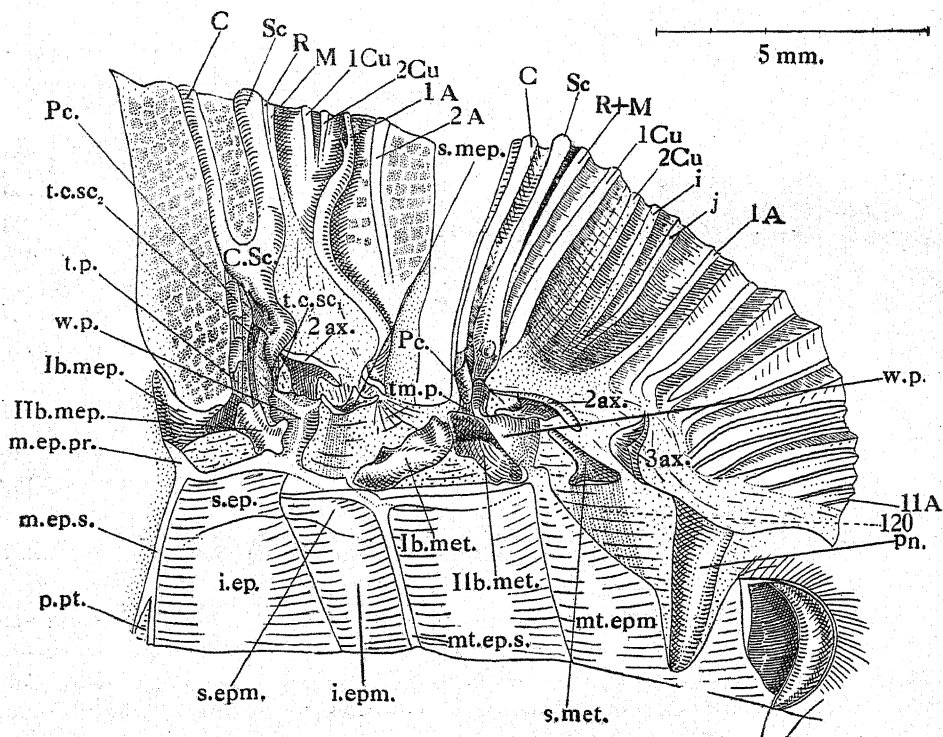


Fig. 2. *Schistocerca gregaria*, ph. *gregaria*.—Upper part of meso- and metapleuron, with the base of the tegmen and wing turned upward to show connections between the epipleurites and the axillary sclerites. Lateral view.

Ib.mep., *IIb.mep.*, first and second basalar mesepipleurites; *Ib.met.*, *IIb.met.*, first and second basalar metepipleurites; *C.Sc.*, costo-subcosta of tegmen; *i.ep.*, infra-episternum; *i.epm.*, infra-epimeron; *m.ep.pr.*, mesepisternal process; *m.ep.s.*, mesepisternal suture; *mt.epm.*, metepimeron; *mt.ep.s.*, metepisternal suture; *Pc.*, precosta of tegmen and wing; *pn.*, postnotum; *p.pt.*, prepectus; *s.ep.*, supra-episternum; *s.epm.*, supra-epimeron; *s.mep.*, subalar mesepipleurite; *s.met.*, subalar metepipleurite; *t.c.sc.1*, tendon joining wing-process with the costo-subcosta at the pointed end; *t.c.sc.2*, tendon joining 2nd basalar mesepipleurite with the costo-subcosta at the nodule; *tm.p.*, tendinous membrane connecting 2nd basalar metepipleurite with the precosta of the wing; *w.p.*, pleural wing-process. (For abbreviations of tegminal and wing veins see legends of Fig. 5.)

sclerite ventrally for the attachment of a portion of the dorsal longitudinal muscle (118). At its posterior margin, the postnotum has a deep dorsal groove all along its length. It represents the antecostal suture above and the 2 phragmata of the first abdominal tergum below; both these structures have been secondarily incorporated into the metanotum and, in this manner, the metanotum has come to possess 2 additional *posterior phragmata* (3 *ph.*).

Karandikar (1939, p. 36) has merged the lateral scutal lobes, and the postscutal and the lateral scutellar areas into a single parascutellar area on each side. Apparently, he overlooked the lateral scutal lobes; the other two structures were apparently included by him in the parascutal lobe, as he did not notice the scuto-scutellar and the reversed notal sutures. He also overlooked the scutal notch here, as in the mesonotum. He mistakenly regarded the scutal process as the postnotal wing-process which is, in fact, wanting in both the meso- and metanotum. He also erred in assuming the 2 anterior and the large median weakly cuticularized patches as sites for muscle attachment on the undersurfaces; in fact no muscles are inserted there.

2. Pleural Region

The pleura of the meso- and metathorax are much less modified than the tergal regions. Like the propleuron, the meso- and metapleuron is each divided by external pleural sutures and their internal ridges into an episternum and an epimeron. The ridges give rise further to pleural apophyses and coxal processes which maintain the same general relation with the furcasternal apophyses of the sterna and the coxal bases of the legs as in the propleuron. Some modifications which have taken place in the pleura are described below in the appropriate places.

(a) MESOPLEURON (Figs. 2, 3 and 10)

The 2 divisions of the pleuron, *viz.*, the mesepisternum and mesepimeron, and the intervening pleural ridge are more highly developed here than in the propleuron.

The entire mesepisternum is bordered anteriorly by an external suture (*m.ep.s.*) and its internal *mesepisternal ridge* (*m.ep.r.*). The ridge is produced upward and slightly forward beyond the mesepisternum into a short *mesepisternal process* (*m.ep.pr.*) leaving a wide notch anteriorly for the insertion of the sterno-pleural intersegmental muscle of propleuron (67). After running a little less than half its length downward, the ridge bifurcates to enclose a sclerite called the *prepectus* (*p.pt.*; lateral arms of presternal strip of Karandikar, 1939). This sclerite continues into the presternite of the sternum and represents the fused anterior parts of the episternum and sternum (Snodgrass, 1935, p. 184). Both the episternum and epimeron are bordered dorsally by an internal ridge; the epimeron having another thin internal ridge lying very close to the main ridge. The mesepisternum is partly divided into a small upper and a large lower area by a distinct horizontal ridge and its external suture, while the mesepimeron is similarly divided by an inconspicuous ridge and its suture. These areas are the *supraepisternum* (*s.ep.*) and *infraepisternum* (*i.ep.*), and, likewise, *supraepimeron* (*s.epm.*) and *infraepimeron* (*i.epm.*) (Snodgrass, 1935, p. 184).

The *pleural ridge* (*p.r.*) is very high and is bent on itself so that its middle part bulges backward and the concavity of the bulge points forward, providing a place for the attachment of a large part of the first abductor muscle of mesocoxa (105). The *mesopleural apophysis* (*p.a.*) projects horizontally inward from the pleural ridge, fits within the shelf of the furcasternal apophysis of the sternum and is joined to it by means of the sterno-pleural muscle (97; Fig. 9). The propleural apophysis (Misra, 1947), on the other hand, is fused with the sternal apophysis without the interpolation of any muscle between them and the prosternal apophysis does not present a shelf-like structure. The diagonal inner half of the mesopleural apophysis is membranous, while the outer half is stiff and biconcave to allow for the attachment of the sterno-pleural muscle.

The dorsal parts of supraepisternum and supraepimeron of either side have become more specialized as they serve for the articulation of the tegmen. They give off together a very prominent pleural *wing-process* (*w.p.*) which is divided into a broad episternal and a very narrow epimeral part by the upward continuation of the pleural ridge; and it is bordered anteriorly and posteriorly by dorsal offshoots of the marginal ridges. Internally, a part of the upper region of the episternum and the entire upper epimeron of the wing-process are greatly thickened obliquely to form an elastic articular lobe (Fig. 10; *a.w.p.*) which is fused with the ventral ridge of the second axillary sclerite (*vide infra*). The remaining upper region of the episternal part remains thin and gives insertion to a tendon (*t.c.sc.*) joining the wing-process ventrally with the proximal end of costo-subcostal vein (Fig. 2; *C.Sc.*) of the tegmen. The pleural ridge is higher in the wing-process than in the main part of the pleuron and gives attachment to the tergo-pleural dorsal muscle (90) of its side (Fig. 10). The wing-process bears anteriorly a wide notch at its base to accommodate the second basalar mesepipleurite.

The dorsal part of the pleuron on either side of the pleural wing-process is split up to form 3 mesepipleurites which are closely associated with the ventral basal region of the tegmen. Two of these, *viz.*, the first and the second basalar mesepipleurites, are episternal and are hinged on each other, while the third is epimeral and is called the subalar mesepipleurite. The *first basalar mesepipleurite* (*I b.mep.*) is subtriangular and is convex externally and concave internally where it is covered by a membrane. Its ventral and a portion of its anterior margins are bordered by thick, internal ridges, while the rest of its anterior and the entire posterior margins remain thin. Anteriorly its outer surface is drawn out to provide an interlocking device for the articulation of this mesepipleurite with the mesepisternal process. Postero-ventrally, the mesepipleurite gives off a prominent disc-like process which is slightly concave ventrally and is circumscribed by a tough membrane, both the concavity and the membrane providing places of insertion for the first and second pronator extensor muscles of the tegmen (91 and 92). The process has a notch on its dorsal surface for the articulation of the second basalar mesepipleurite. The inner wall of this notch gives rise

to a tendon (*t.p.*) which connects this sclerite with the precosta (*Pc.*) of the tegmen. The *second basalar mesepipleurite* (*II b.mep.*) is short and lies in an obliquely antero-posterior direction behind the first; its upper and lower margins are thin, while its central part has an external longitudinal groove and the corresponding internal ridge. Posteriorly it is broad and thick and fits within the anterior notch of the pleural wing-process. Anteriorly its lower margin has a blunt hooked process fitting within the notch of the first basalar mesepipleurite; its upper end gives off a short process continuing into a tendon (*t.c.sc₂*) connecting this mesepipleurite with the costo-subcostal vein of the tegmen. The third or *subalar mesepipleurite* (*s.mep.*) has a peculiar appearance, having a forwardly directed anterior limb and a forked backwardly directed posterior limb. Its broad and concave basal part lies eccentrically beneath the anterior limb, and gives insertion to the depressor extensor muscle of the tegmen (93 i, ii), while a ligamentous membrane connects it dorsally with the second axillary sclerite through the anterior limb and posteriorly with the third axillary sclerite through the forked posterior limb.

Karandikar (1939) failed to notice the mesepisternal ridge and its process, as also the transverse ridges which divide the mesepisternum and the mesepimeron into upper and lower divisions. He did not correctly interpret the morphology of the prepectus which he described as the "lateral arm of the presternal sclerite" (p. 33). As this narrow sclerite is enclosed within the forked mesepisternal ridge and extends almost up to half the lower width of the episternum, it cannot merely be the lateral extension of the presternal sclerite of the sternum. In fact, the lower anterior part of the episternum is divided into a narrow anterior and a broad posterior episternum, the former having fused below with the presternal sclerite of the mesosternum more or less like the similar structure noted in the Hymenoptera by Snodgrass (1925). Karandikar did not describe the articulations of the pleural wing-process with the second axillary sclerite. He did not notice the articulation of the first and second basalar epipleurites, as also that of the latter with the pleural wing-process, and the tendinous connections of all the 3 structures with the precosta and the base of the costo-subcostal vein of the tegmen. He did not clearly make out the relationship of the subalar epipleurite with the second and third axillary sclerites and also missed the ventral process of the first basalar mesepipleurite which gives insertion to pronator extensor muscle (91 and 92) and the basal ventral part of the subalar mesepipleurite which gives insertion to the depressor extensor muscle (93 i, ii). His statement (p. 49) that the basalars "support the ventral region of the costo-subcostal head as well as the side of the second axillary" is erroneous. In fact, the first basalar is connected with the precosta which is quite distinct from the costo-subcostal vein of the tegmen, and only the second basalar and the pleural wing-process are connected with the costo-subcostal vein. These 2 basalar mesepipleurites have nothing to do with the second axillary sclerite.

(b) METAPLEURON (Figs. 2, 3 and 10)

The metapleuron closely resembles the mesopleuron, but there are a few differences. The *metepisternal ridge*, separating the meso- from the meta-pleuron, is stouter than the mesepisternal ridge and gives off, at the level of the spiracle, a small incomplete horizontal ridge which is not long enough to divide the metepisternum into upper and lower divisions. There is no process or notch corresponding to the mesepisternal process and notch, since, unlike the mesopleuron, there is no sterno-pleural intersegmental muscle to be provided with a place of origin in

this region. Further, there being no sclerite corresponding to the prepectus of mesopleuron, the metepisternal ridge does not bifurcate in its lower part.

Along the upper border of the metepisternum there are 2 ridges, viz., a prominent submarginal one and an inconspicuous marginal one. The submarginal ridge arises from the metepisternal ridge and runs posteriorly up to the metapleural ridge. The marginal ridge (Fig. 10), on the other hand, arises from the pleural ridge at the base of the wing-process, runs anteriorly more or less parallel to the submarginal ridge, but becomes indistinguishable as it nears the metepisternal ridge. Its place is taken up by a narrow sclerite the upper margin of which is indented at the junction of meso- and meta-pleuron to provide a place of articulation with the first basalar metepipleurite. The metapleural ridge, with its apophysis and coxal process, closely resembles its mesopleural counterpart.

The *metapleural wing-process* (*w.p.*), although differing in appearance from the mesopleural, has essentially the same general relation with the second axillary sclerite and the wing-base as the mesopleural process has with its corresponding structures. The upper end of the metapleural ridge and the epimeral part of the wing-process together form a more or less elliptical, fleshy *articular lobe* (*a.w.p.*) which, unlike the lobe of the mesopleura, does not include any episternal part. The entire episternal part of the wing-process has the form of a stout projection which shows an internal concavity and is produced at its upper end into an elastic fleshy lobe; this lobe continues into a tendon (*t.c.sc.₁*) connecting the wing-process with the ventral part of the costo-subcostal vein of the wing. In the mesopleural wing-process, on the other hand, as described above, the episternal component does not take a share in the formation of both the articular lobe and the supporting process of the tendon (*t.c.sc.₁*).

The *metepimeron* (*mt.epm.*), unlike the mesepimeron, is irregularly triangular in shape, the irregularity being due to the extension of the postnotum (*pn.*) into it. It has no ridge on its dorsal border.

The 3 metepipleurites markedly differ from the mesepipleurites in appearance and size, as well as in their apodemes. The *first basalar metepipleurite* (Fig. 10; I *b.met.*) is more or less boat-shaped, concave internally and convex externally. Its anterior half gives off a sucker-shaped process (*pr.*), while its posterior half is invaginated to form a large, hollow internal apodeme giving insertion to the first pronator extensor muscle (118). It has no tendinous connection with the precosta of the wing similar to that of the corresponding mesepipleurite. The *second basalar metepipleurite* (II *b.met.*) is also convex externally and concave internally and articulates anteriorly with the posterior surface of the first metepipleurite. Near the upper end of its articulation arises a tendinous membrane (*tm.p.*) which connects it with the precosta (*Pc.*) of the wing and not with the base of the costo-subcostal vein as it does in the corresponding mesepipleurite of the mesopleuron. Just behind the tendinous membrane, the metepipleurite invaginates to form a large internal apodeme giving insertion to the two bundles

of the second pronator extensor muscle (119 i, ii). The third or *subalar metepipleurite* (*s.mt.*) is roughly bell-shaped in appearance with a single long and forwardly directed handle (as against two of the corresponding sclerite in the mesopleuron) and a large body which gives insertion to the two bundles of the depressor extensor muscle (93 i, ii).

The *pleuro-sternal ridge* (*pl.st.r.*) and its suture, which are incomplete in the mesopleuron, are complete and prominent here and they clearly separate the metepisternum from the metasternum, so that there is neither a coxal bridge nor a latero-sternite in this region.

As in the mesopleuron, Karandikar (1939) has not mentioned the articulations and connections between the wing-process and the second axillary sclerite and those between the wing-process and the costo-subcostal vein of the wing. He has also missed the processes and apodeme of the metepipleurites. His statement (p. 37) that "posteriorly the epimeral margin touches the lateral extension of the posterior notal plate and the first abdominal tergite" is only partly correct for, the abdominal tergite really lies posteriorly to the postnotal extension and does not at all touch the epimeron. In his statement that, ventrally, the metepipleuron "meets the metasternal region to form the precoxal bridge showing the sternopleural suture across the same", Karandikar gives the impression that the precoxal bridge and the sterno-pleural ridge are synonyms, which is not the case; the coxal bridge is, in fact, missing in the metapleuron.

3. Sternal Region

The sterna of the meso- and meta-thorax are each bigger than the prosterna, as they provide places of origin for the powerful tergo-sternal muscles of tegmina and wings. They have, however, become modified, like the nota and pleura of these two segments, on account of the fact that the sternal plate of the first abdominal segment is telescoped into the metasternum and the latter into the mesosternum. This telescoping results in the complete suppression of some structures and the great reduction of others among the telescoped sterna; it also results in the fusion of the meso- and meta-sterna to form a large compact 'pterothoracic plastron'*.

(a) MESOSTERNUM (Figs. 3, A-B)

While in the prosternum only the probasisternum and profurcasternum can be made out clearly, in the mesosternum all the elements derived from the common hypothetical segmental plate, the *eusternum*, i.e., the mesopresternum, the mesobasisternum and the mesofurcasternum (sternellum), are clearly represented.

The *mesopresternum* (*m.pst.*) is a narrow but distinct sclerite lying in front of the ventral presternal suture (*pst.s.*) and its dorsal ridge. It becomes fused with the anterior division of the pleuron on either side, thus forming a large compound sclerite which, with its pleural and sternal components, is called the *prepectus* (*p.pt.*). No corresponding sclerite is present in the prosternum.

The *mesobasisternum* (*m.bst.*) is a large heart-shaped sclerite lying medially behind the presternal suture and its ridge. It has 2 small, triangular, thinly

* This fusion of the meso- and meta-sterna corresponds to the fourth case of modified insect sterna mentioned by Snodgrass (1935, p. 167).

cuticularized patches at its hind end, and lacks entirely the prosternal spine of probasisternum.

The *mesofurcasternum* (*fst.*) also is larger in size than the corresponding structure of the prosternum and lies behind and outside the basisternum and the *furcasternal suture* (*fst.s.*; sternacostal suture of Snodgrass, 1935, p. 170) and

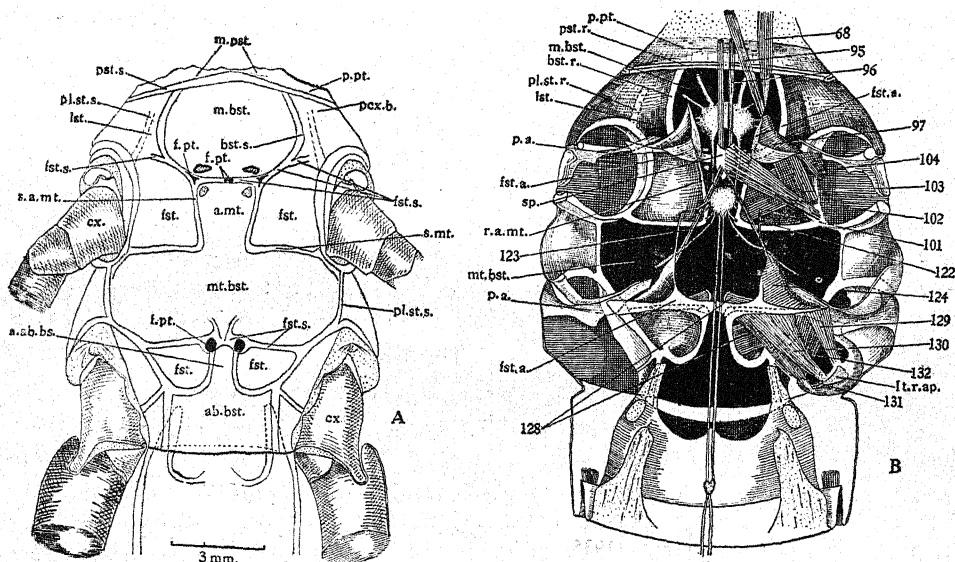


Fig. 3, A-B. *Schistocerca gregaria*, ph. *gregaria*.--A. Meso- and metasternum and a portion of abdomen, with parts of legs attached to them. Ventral view. B. Same, with legs removed and basisternite shaded black, showing the thoracic ganglia, ventral nerve chord and muscles.

a.ab.bs., anterior first abdominal basisternum; *ab.bs.*, posterior first abdominal basisternum; *a.mt.*, anterior metabasisternum; *bst.r.*, mesobasisternal ridge; *bst.s.*, mesobasisternal suture; *cx.*, coxa; *f.pt.*, furcasternal pits, showing invaginations of the apophyses and spinae; *f.st.*, furcasternal lobes of meso- and metasternum; *fst.a.*, furcasternal apophyses; *fst.s.*, furcasterna; suture; *lst.*, latero-sternite; *m.bst.*, mesobasisternum; *m.pst.*, mesobasipresternum; *mt.bst.*, metabasisternum; *p.a.*, pleural apophysis; *pex.b.*, precoxal bridge; *pl.st.r.*, *pl.st.s.*, pleurosternal ridge and suture respectively; *p.pt.*, prepectus; *r.a.mt.*, *s.a.mt.*, ridge and suture respectively of anterior metabasisternum; *sp.*, spina; 68, 2nd pair of ventral longitudinal muscle; 95, 96, 3rd and 4th pairs of ventral longitudinal muscles; 97, pleuro-sternal muscle; 101, anterior rotator muscle of mesocoxa; 102, posterior rotator muscle of mesocoxa; 103, 1st adductor muscle of mesocoxa; 104, 2nd adductor muscle of mesocoxa; 122, 123, 5th and 6th pairs of ventral-longitudinal muscles; 124, pleuro-sternal muscle of metathorax; 128, anterior rotator muscle of metacoxa; 129, 130, 131, 1st, 2nd and 3rd pairs of posterior rotator muscles of metacoxa; 132, adductor muscle of metacoxa.

its ridge. On account of the forward extension of the metabasisternum, this sclerite is split up into two discontinuous *mesofurcasternal lobes* (*fst.*; mesosternal lobes of Karandikar, 1939; and Roonwal, 1946, in the Desert Locust, *Schistocerca gregaria*). Each lobe is bounded anteriorly by its own incomplete suture and ridge, internally by the suture (*s.a.mt.*) and the very prominent ridge (*r.a.mt.*)

of the anterior metabasisternum (mesosternal interspace of Uvarov, 1923; and Roonwal, 1946; and the rectangular process of metabasisternite of Karandikar, 1939), and posteriorly by the suture (*s.mt.*) and the ridge (*r.mt.*) of the posterior metabasisternum. Two deep pits (*f.pt.*; furcasternum of Karandikar, 1939) are seen on the furcasternal suture, one on either side of the anterior boundary of the anterior metabasisternum (*a.mt.*). These pits mark the places of the dorsal invaginations forming the *furcasternal apophyses* (*fst.a.*) which are stouter in the mesosternum than in the prosternum. Each of these apophyses forms a shelf at its free end to accommodate the pleural apophysis (*p.a.*) of its own side to which it is moveably attached by means of sterno-pleural muscles (97). In the prosternum, however, the furcasternal apophyses are fused with pleural apophyses, there being no muscles between them.

A narrow longitudinal sclerite, called the *laterosternum* (*lst.*) lies anteriorly to each mesofurcasternal lobe, outside the mesobasisternal suture (*bst.s.*) and its ridge. It is separated along its greater length from the mesepisternum by a faint, and incomplete *pleuro-sternal suture* (*pl.st.s.*) and its ridge (*pl.st.r.*), but continues into it anteriorly, forming the *precoxal bridge*.

The intersegmental membrane is completely suppressed, while the intersegmental plate or *mesospinasternum* is represented only by the greatly reduced *spina* (*sp.*).

Karandikar's (1939, p. 33) interpretation that the furcasternum is greatly reduced in the mesosternum and is merely represented by "a pair of lateral furcal pits" is, in my opinion, incorrect. According to Snodgrass (1935, p. 170), "the sternal suture (sternacosta or the furcasternal suture) divides the surface of eusternum into a presutural area or basisternum, and a postsutural area, the *sternellum* or *furcasternum*". The region of the mesosternum situated behind and outside the furcasternal suture, called by Karandikar (1939) and Roonwal (1946) the mesosternal lobes, must, therefore, be regarded as *mesofurcasternal lobes*.

(b) METASTERNUM (Figs. 3, A-B)

The metasternum has become even more modified than the mesosternum on account of the enormous size attained by the metabasisternum to provide places of origin for the tergo-sternal muscles of the wings. The *metabasisternum* is a very large sclerite; it has overgrown its own segment in length and extends into the mesosternum as a wedge into the median part of the mesofurcasternum, while in width it has incorporated within itself the region corresponding to laterosternum of mesosternum and has, thus, become considerably broader than the mesobasisternum. That this incorporation has taken place is evidenced by the fact that it is this sclerite that gives origin to the tergosternal (116) and the first rotator extensor muscles (118) of the wing, while their corresponding muscles in the mesosternum (85, 86 and 91) arise from the laterosternum and the precoxal bridge lying clearly outside the basisternum. This sclerite forms two continuous regions—a small anterior metabasisternum and a large posterior metabasisternum. The *anterior metabasisternum* (*a.mt.*) is bounded anteriorly by the mesofurcasternal suture (*fst.s.*) and the spina (*sp.*) of the mesosternum, and

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laterally by its own longitudinal suture (*s.a.mt.*) and the corresponding very prominent ridge (*r.a.mt.*) giving origin to the anterior rotator muscle (101) of the mesothoracic coxa. It is dovetailed into the mesofurcasternum and shows 2 rounded, thinly cuticularized patches at its antero-lateral corners. The *posterior metabasisternum* (*mt.bst.*) is bounded anteriorly by its transverse suture (*s.mt.*) and ridge and a part of the ridge surrounding the mesocoxal cavity, laterally by the pleurosternal ridge, and posteriorly by the metafurcasternal suture and its ridge. It shows 2 crescentic dorsal ridges and their corresponding ventral sutures at its median posterior end. The ridges give origin to a part of the anterior rotator muscle of the metacoxa (128).

The *metafurcasternum* consists of 2 metafurcasternal lobes (*fst.*; metasternal lobes of Uvarov, 1923; Karandikar, 1939; and Roonwal, 1946, in the Desert Locust). Unlike the mesofurcasternal lobes, they are bounded anteriorly by a complete and well developed *furcasternal suture* extending right up to the ridge of the metacoxal cavity.

Both the intersegmental membrane and the spinasternum are completely suppressed here, and even the spina of the mesosternum is wanting.

In my opinion, Uvarov's (1923, p. 32) and Roonwal's (1946) terms, *i.e.*, *mesosternal* and *metasternal interspaces*, for the basisternal parts of the metasternum and the first abdominal sternum respectively, need to be abandoned. These structures, although situated in the middle of the meso- and metasterna respectively (hence called 'interspaces' by these authors), are actually the anterior parts of the basisterna of the metasternum and the first abdominal sternum, and are not visibly separated from the original sclerites by any suture. The use of the prefixes *meso-* and *meta-* before the 'interspaces' of these two segments would assign these basisternal parts to segments to which they do not belong morphologically.

Roonwal (1946) has shown that these structures show phase differences in the Desert Locust.

4. Tegmina (Elytra) and Wings

(a) TEGMINA (Figs. 4, A-P and 5, A-B)

Each tegmen is tough and leathery and consists, as in other winged insects, of two closely apposed laminae which are separately distinguishable in the basal region, but are fused elsewhere. It is really an outward hollow extension of the notum supported ventrally at the base by the pleuron—the notal part forming the axillary and accessory sclerites along with the rest of the tegmen, and the pleural part contributing to the formation of the pleural wing-process and the epipleurites (*vide supra*). It may be divided into 2 parts, *viz.*, (i) a proximal or basal part which articulates dorsally with the mesonotum and ventrally with the mesopleuron; and (ii) a distal part, or tegmen proper, which alone is used for flight.

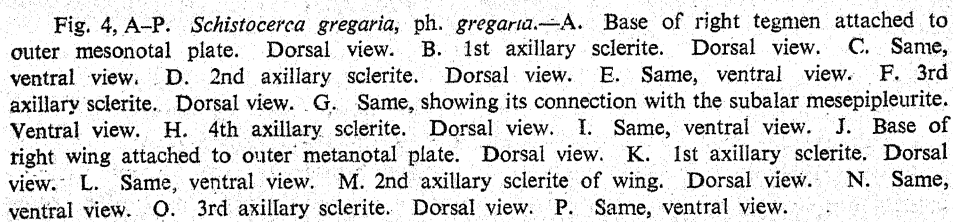
(i) *The proximal or basal part of tegmina*.—Each basal part consists of 3 epipleurites on the undersurface (which, being pleural derivatives, have been already described under the pleural region), and 4 axillary and 4 accessory sclerites on the upper surface. The importance of this region lies in the fact that all the principal veins of the tegmen are suitably hinged on this region, thus facilitating the movement of tegmen. Therefore, a careful study of its component

parts is necessary to understand the mechanisms of folding and unfolding of the tegmen and to determine the homologies of the veins on the basis of their attachment to the component parts.

The *first axillary sclerite* (1 *ax.*) is subquadrangular; it lies, in an obliquely vertical plane, just externally to the scutum and behind the prescutum (*d.ps.*), and has its proximal margin at a lower level than the distal. It is thick and strongly cuticularized, except for a small posterior part which is thin and scooped ventrally. The proximal part of its ventral surface provides a place for the origin of the axillary bundle of the trochanteral depressor muscle (109 ii), while the distal part is slightly drawn out to fit in with the second axillary sclerite. On the dorsal surface the sclerite gives off proximally a broad upturned process (*pr.p.*) for attachment, by means of a ligament, with the second prong of the notal wing-process. Anteriorly, the sclerite gives off a long and curved process (*a.p.*) a part of which overlies the first prong of the notal wing-process (Fig. 1A *n.w.*₁), while the remaining part lies beneath the inner process (*i.pr.*) of the second sclerite. Posteriorly this sclerite gives off a small and straight process (*p.p.*) which fits, through a ligament, into a notch of the scutum (*sct.n.*).

The *second axillary sclerite* (2 *ax.*) is a subtriangular piece which lies horizontally between the first axillary and the proximal median accessory sclerites. Anteriorly to it is situated the costo-subcostal sclerite of the tegmen whose two condyles (*co.*₁ and *co.*₂) moveably rest on its antero-lateral border, while posteriorly it is fused with the third axillary sclerite. The apex of this sclerite is directed backward and each of its two basal ends is produced into a process, the inner process (*i.pr.*) is blunt and rests on the anterior process (*a.p.*) of the first axillary sclerite, while the outer process (*o.p.*) is fused with the base of the distal median accessory sclerite and the radial vein. The outer process thus forms the main hinge on which the anterior part of the tegmen moves on the axillary element. Ventrally, the sclerite gives off a vertical longitudinal ridge (*l.r.*), whose obliquely disposed middle part is strongly cuticularized and rests on the pleural articular wing-process (Fig. 2) to serve as a pivot for the tegmen, and whose posterior part is slightly curved and joins, through a broad ligament, the suralar mesepipleurite (Fig. 4 E) and the third axillary sclerite.

The *third axillary sclerite* (3 *ax.*) is an elongated sclerite which is situated externally to the fourth one and lies in an obliquely horizontal plane when the tegmen is extended, but becomes vertical when the latter is flexed. This sclerite has, therefore, the widest range of movement. It is folded on itself along its longitudinal axis, thus forming a prominent dorsal groove (*gr.*) and a ventral ridge (*ri.*) between the two folds. The inner part of the anterior fold diverges to form a large and forwardly directed inner process (*i.p.*), its middle part remains vertical and is fused with the second axillary and the proximal median accessory sclerites, while its outer part forms a bulla-like swelling (*b.s.*). On the ventral surface of the inner process (*i.p.*) is inserted the flexor muscle of the tegmen (94), while the external end of the posterior fold fuses with the base of the first anal vein.



a.p., anterior process of 1st axillary sclerite; *a.p.scl.*, arm of postscutellum; *a.s.*, anal shaft of wing; *b.s.* bulla-like swelling; *co.*₁, *co.*₂, anterior and posterior condyles respectively of the

costo-subcostal accessory sclerite; *C.Sc.s.*, costo-subcostal accessory sclerite; *d.m.*, distal median accessory sclerite; *d.nch.*, deep notch of 2nd axillary sclerite of wing; *d.ps.*, distal part of prescutum; *gr.*, longitudinal groove of 3rd axillary sclerite; *i.p.*, inner process of 3rd axillary sclerite; *i.pr.*, inner process of 2nd axillary; *l.dep.*, longitudinal depression of 2nd axillary of wing; *l.r.*, longitudinal ventral ridge of 2nd axillary; *l.scl.*, lateral scutellar lobes; *l.sct.*, lateral scutal lobe; *o.p.*, outer process of 2nd axillary; *p.m.*, proximal median accessory sclerite; *p.p.*, posterior process of 1st axillary; *pr.p.*, proximal process of 1st axillary; *r.g.*, radial groove; *ri.*, ventral ridge of 3rd axillary; *scl.*, scutellum; *sct.*, scutum; *s.mep.*, subalar mesepipleurite; *s.met.*, subalar metepipleurite; **94**, flexor muscle of tegmen; **109 ii**, scutal bundle of depressor muscle of trochanter; **121 i, ii**, flexor muscle bundles of wing.

Ventrally the ridge of the sclerite gives off a leaf-like apodeme (Fig. 4 E, *ap.*) connecting the sclerite, by means of a broad ligament, with the forked limb of the suralar mesepipleurite and the longitudinal ridge of the second axillary sclerite, thereby serving to support the axillary sclerite from below.

The *fourth axillary sclerite* (4 *ax.*) is a small \cap -shaped sclerite, convex dorsally and concave ventrally. It lies distally to the lateral lobe of the scutellum (*l.scl.*) with whose up-turned outer margin it is interlocked by means of its downwardly bent proximal margin. Its proximal limb is thick anteriorly but tapers posteriorly and is firmly connected with the prealar arm of the metanotal prephragma, while its distal limb is narrow throughout and is joined to the proximal end of the third axillary sclerite by means of a membrane.

Karandikar's (1939) description of the axillary sclerites is incomplete and at places erroneous. In the first sclerite he has missed the upturned process (*pr.p.*, by which the sclerite articulates with the scutum through a ligament) and the place of origin of the axillary bundle of the depressor muscle (109 ii), and has also not stated how this sclerite is joined to the second axillary sclerite. In the second sclerite he has missed both the inner (*i.pr.*) and outer processes (*o.p.*). Further, his description of the longitudinal ridge is inadequate and he erroneously describes this ridge as resting on the "wing base" (p. 49) instead of on the pleural wing-process. His statement, that the sclerite is "immovably joined to the head of the costo-subcostal basal sclerite" is also incorrect, as the latter sclerite really articulates moveably on the second sclerite by means of 2 condyles. Karandikar's description of the third axillary sclerite fails to give a clear picture of this flexor apparatus of the tegmen. He has not noted the inner process (*i.pr.*), the place of insertion on it of the flexor muscle (94), the ventral ridge connecting it with the second sclerite and the subalar mesepipleurite. He has described the fourth axillary sclerite as a "small roundish sclerite", while in fact it is \cap -shaped. He seems to have overlooked the gap between the two limbs of the sclerite, possibly because he overlooked the prealar arm of the metanotal prephragma which largely occupies the gap.

There are 4 accessory sclerites which intervene between the axillary sclerites and the principal veins of the tegmen; these are: the 2 median sclerites, the costo-subcostal sclerite and the precosta.

The *median accessory sclerites* consist of 2 subequal and adjoining sclerites—a proximal one (*p.m.*) and a distal one (*d.m.*)—the distal being a little ahead of the proximal. They are concave ventrally where they are covered over by a large membrane joining together the outer border of the second axillary sclerite, the dorsal margin of the suralar mesepipleurites, the inner part of the ridge of the third axillary sclerite, the basal part of the anal vein, the ventral surface of

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the radial vein and the posterior margin of the costo-subcostal sclerite (Fig. 2). This *proximal sclerite* (*p.m.*) is triangular in appearance with its apex pointing forward. It is situated externally to the second axillary sclerite, whose outer margin it overlaps, and is fused with the outer anterior margin of the third axillary sclerite. It lies in an obliquely horizontal plane when the tegmen is extended, but becomes vertical to the second sclerite with its outer margin directed upward when the tegmen is flexed. The space between the two median sclerites is bridged over by a membrane, called the *basal fold* or *plica basalis*. The *distal sclerite* (*d.m.*) lies in a horizontal plane when the tegmen is extended but slopes externally downward when the tegmen is flexed. It is intimately fused anteriorly to the second axillary sclerite and the radial vein; posteriorly it is embedded in a membrane joining it with the base of the first anal vein; and internally it has a broad and deep median notch bridged over by the basal fold. The bulk of the sclerite is evaginated, excepting the outer border which lies flat, thus providing a broad oblique groove within which slides the basal part of the first anal vein when the tegmen flexes.

The *costo-subcostal accessory sclerite* (*C.Sc.s.*) overlaps the proximal part of the costo-subcosta (*C.Sc.*) which is concealed beneath it (*vide infra*) and serves as an intermediary piece dorsally between it and the notum. It facilitates the vertical and horizontal movements of the anterior part of the tegmen through its 2 condyles. These condyles are given off from it, one at its inner end (*co.*₁) and the other (*co.*₂) at its posterior margin. One condyle moves freely within the vertical notch of the distal prescutum (*d.ps.*) and on the inner process of the second axillary sclerite, while the other (*co.*₂) moves on the base of the outer process of the sclerite.

The humeral plate or *precosta* (*Pc.*) of the tegmen is a short sclerite which lies preaxially to the costo-subcosta (*C.Sc.*) and the accessory sclerite of the same name; ventrally it gives off a branch which is attached to the first basalar mesepipleurite by means of a tendon (Fig. 2, *t.p.*).

Out of the 4 accessory sclerites, Karandikar (1939) has mentioned only the costo-subcostal, in which again he has missed the posterior condyle and has not stated how it is connected with the common base, *i.e.*, with the costo-subcosta. He has completely missed the first two and the last sclerites.

(ii) *The tegmen proper.*—Each tegmen proper is divisible into 3 regions: the preaxial remigial, the anal, and the postaxial jugal. The first two are separated from one another by flexible *anal folds* (*a.f.*), and the last two by similar *jugal folds* (*j.f.*); the tegmen can flex or fold along these folds alone. When the locust is at rest, the tegmina lie over the pterothorax and the abdomen, their distal third extending beyond the abdomen. In spirit-preserved specimens, the tegmen of the right side generally overlaps that of the left, although in a few specimens I have also seen the opposite disposition of tegmina. The jugum is completely folded beneath the anal region and the anals of the two sides together form an arch over the body which is flanked on either side by the remigium.

There is a pattern of dark brown patches on the tegmina, but their positions show considerable individual variation.

The *remigium* is on the whole the broadest and toughest of the 3 regions of the tegmina. It is membranous for a short distance along its proximal anterior margin and has a small rounded sclerite called the *tegula* (Fig. 1 B, *tg.*). Between the two apposed walls of the remigium lie a large number of veins, viz., the *costa*, *subcosta*, *radius*, *medius*, *cubitalis* and *precosta* (*Pc.*). The last one, on account of its serving to connect the tegmen with the pleura below, is regarded as an accessory sclerite and not a vein; it has, therefore, been described under the accessory sclerites. The region of the remigium behind each vein is called after the name of the vein preceeding it. The *costa* and *subcosta* are unbranched and arise from a common base called the *costa-subcosta* (*C.Sc.*), the distal half of which alone is visible dorsally, the proximal half being covered by the accessory sclerite of the same name. Ventrally the proximal half of the costo-subcosta appears very thick, is nodular in the middle and pointed at the proximal end (Fig. 2, *C.Sc.*). At the nodule the costo-subcosta is connected by a tendon (*t.c.sc.*₂) with the muscle-controlled second basalar mesepipleurite, while at the pointed end it is intimately connected with the pleural wing-process by means of another tendon (*t.c.sc.*₁): thus the costo-subcosta is hinged with the notum through an accessory sclerite (*C.Sc.s.*) and with the pleural region through the tendons. This elaborate attachment of the important first and second veins to the notum as well as to the pleuron has not been noted in any other Acridiid grasshopper whose muscles have been so far studied.

The *costa* runs outward almost parallel to the preaxial margin for about half the length of the latter, then bends forward and runs obliquely outward to merge into the margin. The *subcosta* is the stoutest vein in the tegmen; it runs outward and also merges into the preaxial border of the tegmen shortly before its distal end. The *radius* has a triangular base fused at its proximal narrowed end with the anterior border of the distal median accessory sclerite close to the latter's fusion with the second axillary sclerite. Its posterior basal border is thickly cuticularized and slopes towards the anterior basal border of the first anal vein which also slopes towards it at this place, the two sloping surfaces together forming the *radial groove* (*r.g.*). The vein runs outward closely parallel to the subcosta and, after covering about half the length of the tegmen, bifurcates into an anterior unbranched radius proper and a posterior radial sector vein, the latter further dividing into 6 radial branches, thus bring the total number of radial veins to *sev n.* The *medius* lies externally to the base of the radius with which it appears to be fused for a short distance, and then gives off 4 branches; the common part of the third and the fourth branches (*M*₃ and *M*₄) is connected with the first cubital vein by means of a *medio-cubitus* (*M-Cu.*) transverse vein, thus enclosing a closed *medius cell* between the medius and the cubitus. The first and second cubitus are unbranched, and arise together close to the place of origin of the medius between the bases of the radius and the first anal vein;

both the cubital veins run outward and together merge into the postaxial border of the remigium, the second vein running closely parallel to the anal fold. This fold arises in front of the anal vein and runs outward closely parallel to the second cubital and the first anal veins.

The *anal region* of the tegmen is a narrow, tough, triangular part lying between the anal and the jugal folds; it is traversed by 2 unbranched anal veins which lie within the anterior third of its width, while the remaining two-thirds behind it is tough but devoid of veins. The first anal vein is fused behind the posterior fold of the third axillary and proximal median sclerites; in its proximal part it takes a sinuous course, bends forward almost at a right angle to lie within the oblique posterior groove of the distal median sclerite, then takes a twist outward almost at a right angle again. Just externally to the twist, it gives off a broad blade-like projection sloping forward into the radial groove. This projection allows the strongly cuticularized posterior basal border of the radial vein to slide on it in an obliquely upward direction when the tegmen flexes. Beyond this region the vein runs outward behind the anal fold to the posterior border of the tegmen. The second anal vein is stouter than the first and arises from the place of fusion of the first vein with the third axillary sclerite; it runs outward to cover about half the length of the anal region and then curves backward to merge into the postaxial margin of the tegmen.

The *jugum* is a small, membranous, triangular region of the tegmen, and serves to connect the tegmen with the third and fourth axillary sclerites and the postscutellum. It has no veins and remains folded obliquely beneath the anal region when the locust is in flight.

Karandikar's (1939) description of the venation of adult tegmen and the hind-wing of the Desert Locust is so mixed up that it is difficult to distinguish where he is referring to the tegmen and where to the hind-wing. He does not specify the number of branches of the radial sector and has mentioned only 2 branches of the medius, while I find 7 branches in the radius* and 4 in the medius. He describes (1939, p. 46), "one or two cubitals", which may either mean individual variation in the tegmen or one cubital in the tegmen and two in the hind-wing; further, he mentions a cubital vein with a proximal cubital sector and an uncertain number of distal branches. I find, however, that the tegmen has 2 unbranched cubital veins in all cases. It is probable that this confusion in Karandikar's account occurred because he missed that part of the common stem of the 3rd and 4th medius branches which connect them with the principal medius vein. This strange omission, both in the developmental stages (1945) and in the adult tegmen (1939) seems to have led him to call the common stem of the 3rd and 4th medial branches as cubital vein and its branches. I have checked this point carefully in the tegmental venation of the adult and find that although my description of the radius and medius veins differs from that of his (1939), it agrees with the photograph of the adult tegmen he has given in both of his papers (1939, 1945).

Karandikar (1939, 1945) has not mentioned a transverse medio-cubital vein forming the closed medius cell, although he does mention a cross vein called *x* (different from the medio-cubital

* In a later paper Karandikar (1945), while dealing with the post-embryonic development and tracheation of the tegmina and wings, does mention 7 radial branches, but only 2 branches of medius in the 4th instar.

transverse vein of my account) arising a little behind the bifurcation of his main cubital vein and running obliquely to join his cubital sector. I do not find this cross vein in any of my specimens; probably the cross vein he mentions may only be the continuation of the first cubital vein itself beyond the medio-cubital transverse branch. Again, his statement that the second anal vein ends blindly is not correct, for the vein actually reaches the posterior margin of the tegmen.

(b) WINGS (Figs. 4, A-P and 5, A-B)

The wings are membranous and much wider in expanse than the tegmen. Each wing, in its basal part, possesses all the structures present in the tegmen (except the costo-subcostal accessory sclerite) and only differs from it in appearance. These differences are included in the following account:—

(i) *The proximal or basal part of wings.*—The *first axillary sclerite* is more or less quadrilateral in shape. Its anterior process (*a.p.*) is short and straight but, unlike the corresponding process of tegmen, it is given off from its distal margin and is truncated. No muscles are inserted on this sclerite. In the *second axillary sclerite* the outer process (*o.p.*) is less pigmented, and the sclerite has, on its anterior margin, a deep notch (*d.nch.*) within which is accommodated the large condyle of the costo-subcosta, while posteriorly it is greatly prolonged into a narrow process. The sclerite has a broad longitudinal depression (*l.dep.*) near its distal margin where it is overlapped by the proximal median accessory sclerite. The *third axillary sclerite* is not so complicated in structure as that of the tegmen; it is only partially folded along its longitudinal axis, and consequently its dorsal groove is inconspicuous and the ventral ridge is wanting altogether along with the tendinous connection with the suralar metepipleurite. In the latter sclerite there is only one limb as against 2 of the suralar mesepipleurite (*vide supra*). The inner process (*i.p.*) is a large structure which can be identified by the insertion it provides to the powerful flexor muscle of the wing (121) beneath it. The bulla-like swelling (*b.s.*) is also large here. The *fourth axillary* is rod-shaped.

In the wing there are only the following 3 accessory sclerites, as against 4 in the tegmen:—A proximal median, a distal median, and a precostal; the costo-subcostal accessory sclerite of the tegmen is here incorporated within the greatly developed costo-subcosta itself. The *proximal median sclerite* (*p.m.*) is large and its inner border overlaps the longitudinal depression of the second axillary sclerite, while the *distal median sclerite* (*d.m.*) is rudimentary and is completely fused externally with the compound base of the radius and medius veins. Instead of lying by the side of the proximal sclerite, as in the tegmen, this distal sclerite lies ahead of it, as if it had moved radially forward in response to the greater expanse of the wing. The *precostal sclerite* (*Pc.*) is subtriangular; proximally it is connected by means of a tendon (*tm.p.*) with the second basalar metepipleurite, instead of the first as in the tegmen, and distally with the costal vein (Fig. 2),

As in the tegmen, Karandikar (1939) has altogether missed the two median accessory sclerites of the wing.

(ii) *The wing proper* (Figs. 5, A-B).—In the *wing-proper* only the following 2 areas can be distinguished clearly, as against 3 in the tegmen: the narrow

remigium and the greatly expanded fan-shaped anal region; the jugum, which serves to connect the wing with the postscutellum, is rudimentary.

In the *remigium*, the costo-subcosta is greatly developed and incorporates within itself the costo-subcostal accessory sclerite of the tegmen, as is evidenced by the fact that it bears 2 condyles of the accessory sclerite of the tegmen. The first or inner condyle is large and fits in the deep notch of the second axillary sclerite instead of in the notch of the prescutum of the tegmen (which is rudimentary in the metanotum). The second condyle moves on the base of the

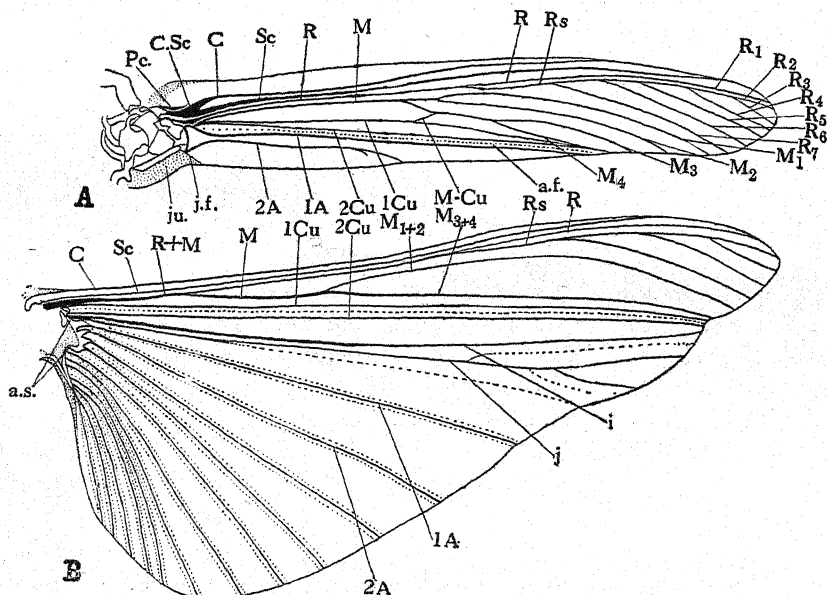


Fig. 5, A-B. *Schistocerca gregaria*, ph. *gregaria*.—A. Right tegmen, showing veins. The irregular patches on the tegmen have not been shown. B. Right wing. The basal part has been omitted.

a.f., anal fold; a.s., anal shaft of wing; 1A, 2A, etc., 1st, 2nd anal veins, etc.; C., costa; C.Sc., costo-subcosta; 1Cu, 2Cu, etc., 1st, 2nd cubital veins, etc.; j.f., jugal fold; ju., jugum; M, M₁–M₄, principal medius and four of its branches; M–Cu, medio-cubital cross vein; R, Rs and R₁–R₇, principal radius, radial sector and seven of their branches; Sc, subcosta.

outer process of the same axillary sclerite. The triangular base of the radial vein of tegmen is greatly reduced here and represents the fused basal parts of both radius and medius veins; its proximal narrowed end is truncated and is fused with the distal median sclerite (*d.m.*). The common radio-medial stem runs outward for about one-fifth the length of the wing and then breaks into its components veins, viz., the radius and medius. The radius gives out the principal radial branch anteriorly and the radial sector posteriorly; the latter divides into 4 branches, thus bringing the number of radial branches to 5, as against 7 in the tegmen. The medius bifurcates into 2 branches; the anterior branch represents

the joint stem of M_1 and M_2 and the posterior branch represents that of M_3 and M_4 of the tegmen. The first cubital arises close to the radio-medial base in the radial groove and runs anteriorly and parallel to the anal fold; the second cubital runs behind the anal fold.

Behind the second cubital lie two problematic veins arising from a common base but not from the large anal shaft (*a.s.*); hence they cannot be regarded anal veins.

More or less similar veins have been noted in the wing of *Dissosteira carolina* by Snodgrass (1929) where they have been regarded as branches of first principal anal vein. Snodgrass has shown the common stem dividing into an anterior *i* and a posterior vein subdividing into *j* and *k*; in *Schistocerca gregaria*, however, I have noted only *i* and *j* veins. The first anal arises from the anal shaft from which all the other 11 anal veins arise subsequently.

Karandikar (1945) has figured only 3 branches of the radial sector in the wing of *S. gregaria* from the fourth hopper instar onward, while I find that there are 4 in the adult; he has made no mention of the problematic *i* and *j* branches and describes 13 anal branches arising from the anal shaft, while I find that there are only 12 of them.

5. Pterothoracic Legs (Figs. 6, A-F, 7, A-C and 8)

The pterothoracic legs, besides effecting locomotion, have to provide secure places for the origin of the tegminal and wing muscles. On account of this additional function, their structure has become modified, as compared to that of the prothoracic legs. These changes are far more pronounced in the basipodite region than in the telopodite region of these legs.

(a) BASIPODITE

This differs from the prothoracic basipodite (Misra, 1947) in the following respects:—

The *trochantin* (*tn.*) is thinly cuticularized and is small in the mesocoxa and smaller still in the metacoxa; it shows in fact a progressive reduction from the procoxa to the metacoxa.

In disposition, the pterothoracic *coxae* are directed downward and backward, while the procoxae project downward and slightly forward from its pleuro-coxal articulation. If the line passing through the pleuro-coxal articulation dorsally and the place of insertion of adductor muscle ventrally be regarded as the *vertical axis*, it will be found to be almost at right angles to the longitudinal axis of the locust both in the meso- and meta-coxae, but in the procoxa it is inclined with a slight torque (twist) forward through about 60° and is not *quite* vertical. As a result of this, the trochantin is slightly preaxially dorsal in position in the pterothorax, while it is entirely preaxial in the procoxa, and the external protuberance of the coxa (*pr.cx.*) is progressively removed posteriorward from the pro- to the meta-coxae. In the distal border, the dorsal notch (*d.n.*) of the procoxa is broad and deep, of the mesocoxa shallow, and of the metacoxa broadest and most prominent; this notch is also progressively removed towards the postaxial side from the pro- to the meta-coxae. The ventral notch (*v.n.*), on the

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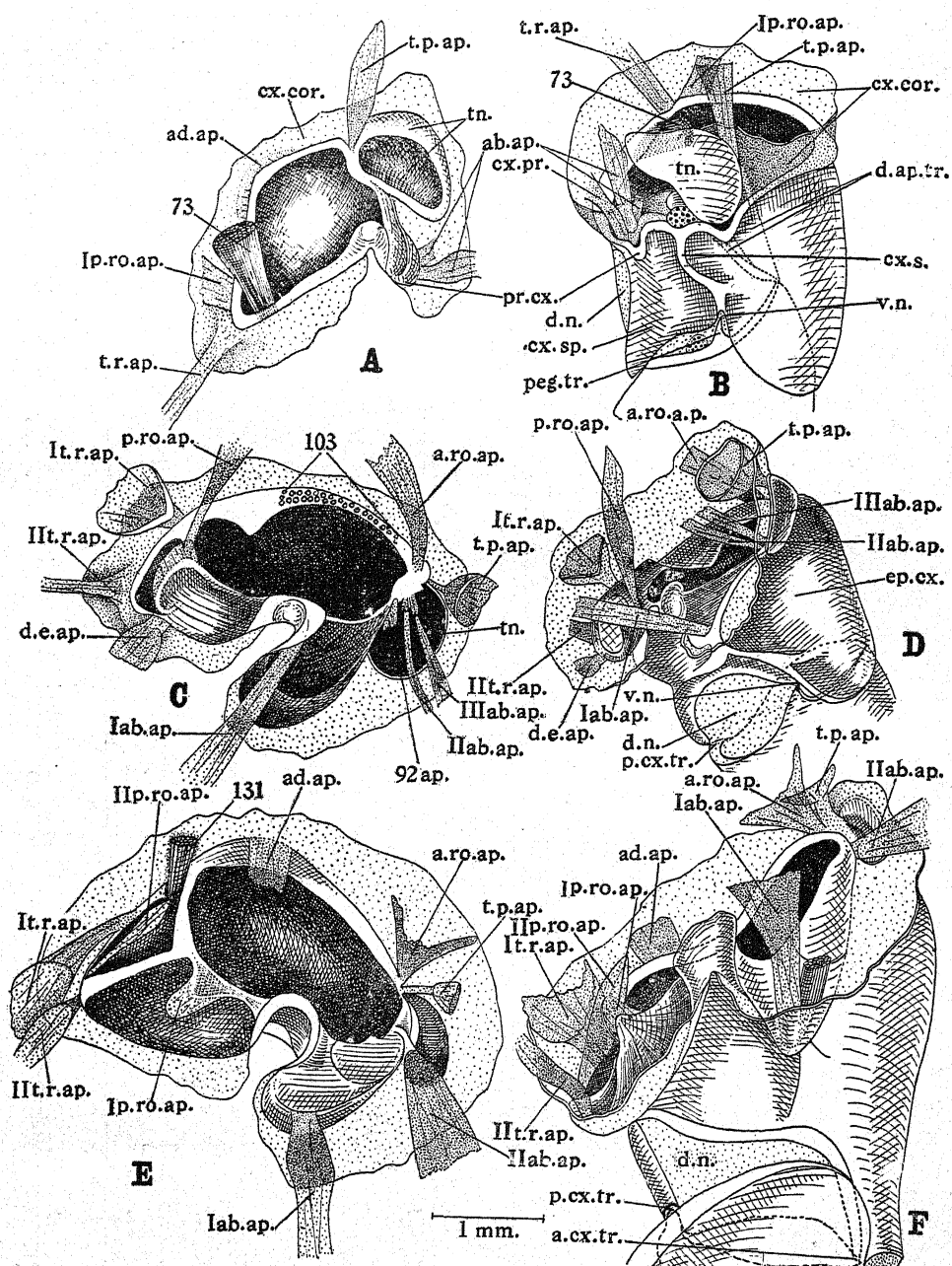


Fig. 6, A-F. *Schistocerca gregaria*, ph. *gregaria*.—A. Inner view of base of procoxa, showing attachment of apodemes and a muscle. B. Right procoxa and part of trochanter. Anterior view. C. Inner view of base of mesocoxa, showing increased basicostal surface for

attachment of tegminal muscles. D. Mesocoxa and part of trochanter attached to it. Antero-dorsal view. E. Inner view of base of metacoxa, showing increased basicostal surface and attachment of apodemes and a muscle. F. Metacoxa and part of trochanter and the overlapping dorsal process of femur. Antero-dorsal view.

ab.ap., I-III *ab.ap.*, abductor apodemes; *a.cx.rt.*, anterior coxo-trochanteral articulation of metacoxa; *ad.ap.*, adductor apodeme; *a.ro.ap.*, anterior rotator apodeme of meso- and metacoxa; *cx.cor.*, coxal corium; *cx.pr.*, coxal process or pleural ridge in procoxa; *cx.s.*, coxal suture; *cx.sp.*, procoxal spine; *d.ap.tr.*, depressor-extensor apodeme of mesocoxa; *d.n.*, dorsal notch of distal border of coxa; *ep.cx.*, episternal part of mesocoxa; *p.cx.tr.*, posterior coxo-trochanteral articulation; *peg.tr.*, peg-like anterior articular process of trochanter; *pr.cx.*, external protuberance of coxa; *p.ro.ap.*, I-II *p.ro.ap.*, posterior rotator apodemes; *tn.* trochantin; *t.p.ap.*, tergal promotor apodeme; *t.r.ap.*, I-II *t.r.ap.*, tergal remotor apodemes; 73, 2nd posterior rotator of procoxa; 92 *ap.*, 2nd rotator of tegmen; 103, 1st adductor of mesocoxa; 131, 3rd posterior rotator of metacoxa.

other hand, is removed towards the preaxial direction in the mesocoxa (so that the dorsal and ventral notches become adjacent) and is altogether absent in the metacoxa. The coxal spine (*cx.sp.*) is absent in the meso- and meta-coxae.

In order to provide places of origin for the flight muscles, the meso- and meta-coxal *basicostae* have increasingly widened in the dorsal region in comparison to that of the procoxa. The procoxal basicosta is somewhat wide in the region of the coxal protuberance anteriorly to its pleuro-coxal articulation (Fig. 6, A); those of the meso- and meta-coxae (Figs. 6, C, E) are wide both anteriorly and posteriorly to this articulation. It is weakly cuticularized in the procoxa, moderately so in the mesocoxa, and strongly cuticularized in the metacoxa. In the latter, the posterior part gives out a small additional process (I *p.ro.ap.*) for the insertion of the first posterior rotator muscle. The posterior part of mesobasicosta (called its epimeral region, *vide infra*) provides places of origin for the depressor extensor muscle, the apodeme (*d.e.ap.*) of another bundle of this muscle of tegmen, for the second adductor muscle and posterior rotator apodeme (*p.ro.ap.*). The corresponding region of the metacoxa gives origin to depressor extensor muscle, and to the first (I *p.ro.ap.*), second (II *p.ro.ap.*) and third posterior rotator apodemes, and the tergal remotor apodeme. The anterior part or episternal region of the mesocoxa, on the other hand, provides attachment to the first abductor apodeme (I *ab.ap.*) alone, while that of the metacoxa gives attachment to the second rotator of the wing (119 ii) and the first abductor apodeme. The cuticularization of the meso- and meta-coxal basicosta is almost uniform ventrally. This cuticularized portion is wide in the median region in the mesocoxa only where it provides a place for the origin of the first adductor muscle (103) on its proximal face; on its distal (opposite) face it provides insertion for the coxal branch of the depressor of the trochanter. In the pro- and meta-coxae, on the other hand, the basicosta is uniformly wide in the ventral region.

The *coxal suture* has also shifted medially in the mesocoxa from its preaxial position in the procoxa, but has altogether disappeared in the metacoxa. In the procoxa it starts proximally from the basicosta preaxially to the external protuber-

ance and runs distally to the ventral notch, whereas in the mesocoxa it is in line with the pleural suture. On account of this continuity with the pleural suture, the mesocoxa is distinguishable into an anterior *episternal* (*ep.cx.*) and a posterior *epimeral* region, corresponding to similar divisions of the pleural region. This suture of the mesocoxa starts from the external protuberance itself, runs preaxially and terminates at the ventral notch distally. Near its proximal end it also gives out a short branch posteriorly which runs parallel to the basicostal suture and terminates at the postaxial thickening of the coxa; this branch divides the epimeral region of the coxa into a large proximal part and a small distal part lying between the coxal and the postaxial distal thickening.

The places of *trochanteral articulations* at the distal border of the coxae form a hinge on an obliquely antero-posterior axis; these places are alike in the pro- and meso-coxae, but differ in the metacoxa. In the former two, the anterior articular place (for the peg-like process or trochanter, *p.g.tr.*) lies at the ventral notch (*v.n.*) and the posterior one at the postaxial thickening (*p.cx.tr.*), while in the metacoxa the anterior and posterior limbs of the greatly developed dorsal notch themselves provide the two articular places of the hinge; the ventral notch is absent here. In the metacoxa, the anterior (outer) limb of this notch forms a blunt articular process (*a.cx.tr.*), while the posterior (inner) limb bears a small but deep and strongly cuticularized pocket (*p.cx.tr.*) for a second articulation of the trochanter. The axis of articulations, however, remains the same, *i.e.*, antero-posterior, as in the other two coxae.

The apodemes related to the pterothoracic basipodite are as follows:—The *tergal promotor apodeme* (*t.p.ap.*) is broad and funnel-shaped in the pterothoracic coxae. It is large in the mesocoxa and small in the metacoxa; in the procoxa it is sabre-shaped. In all the 3 coxae it is attached to the lower margin of the trochantin (*tn.*) and the adjoining basicosta. There are 2 *tergal remotor apodemes* in each of the meso- and meta-coxae, and only one in the procoxa—the apodeme in the procoxa seems to be homologous with the second tergal remotor apodeme of the other two coxae on account of the similarity of its place of origin and appearance. The first apodeme (*I t.r.ap.*) is broad and shallow in the mesocoxa, and long and narrow in the metacoxa; it is inserted postero-ventrally at the junction of the basicosta with the coxal corium (*cx.cor.*). The second apodeme (*II t.r.ap.*) is tape-like in both these pterothoracic coxae and is also inserted posteriorly at the junction of the basicosta with the corium. The *anterior rotator apodeme* (*a.ro.ap.*) is tape-like in the mesocoxa, and wedge-shaped in the metacoxa; in both it is inserted at the anterior corner of the coxal base close to the tergal promotor apodeme; there is no corresponding apodeme or muscle in the procoxa. There is only one *posterior rotator apodeme* (*p.ro.ap.*) in the pro- and meso-coxae, and 2 in the metacoxa. Although there are 2 posterior rotator muscles in the procoxa and 3 in the metacoxa, the second muscle of the procoxa and the third muscle of the metacoxa are inserted directly on the postero-dorsal part of basicosta of the pro- and meta-coxae respectively. There are 3 abductor apodemes

in the meso-, 2 in meta- and only one in pro-coxae. The first apodeme (I *ab.ap.* = third abductor of *Dissosteira carolina*, Snodgrass, 1929), which is present in all the 3 coxae, is broad and tape-like, is inserted in all the 3 coxae at the external protuberance just in front of the pleuro-coxal articulation and is covered from the outside by the coxal corium. The second (II *ab.ap.*) and the third (III *ab.ap.*) apodemes of mesocoxae are long and slender, lie close together and are inserted at the anterior angle of the basicosta internally to the trochantin. The second apodeme of the metacoxa is broad and wedge-shaped, and is inserted at the anterior angle of the basicosta internally to the trochantin. The third apodeme is absent in the metacoxa. The *adductor apodeme* (*ad.ap.*) is not well-marked in the procoxa, only a trace of it being discernable at the junction of the corium with the basicosta on the ventral side. In the mesocoxa there is no apodeme for the 2 adductor muscles directly inserted on the basicosta. In the metacoxa there is one broad and short apodeme on the ventral part of the basicosta.

There are two special apodemes in the mesocoxa: one for the second rotator muscle of tegmen (92, *ap.*) and for the depressor extensor muscle (*d.e.ap.*), while in the metacoxa there are no apodemes for the wing-muscles because the attachment of these muscles lies directly on the greatly developed basicosta itself. The apodeme for the second rotator muscle of tegmen (92, *ap.*) is broad and very short and arises anteriorly on the basicosta internally to the second abductor apodeme. The depressor extensor apodeme of the mesocoxa (*d.e.ap.*) is broad and funnel-shaped and arises postero-dorsally on the epimeral basicosta above the second tergal remotor apodeme.

(b) TELOPODITE (Figs. 7 and 8)

The trochanters of the pro- and meso-thorax are more or less similar except that in the latter the trochanteral ridge is more pronounced, the peg-like anterior articular process (*peg.tr.*), which is situated preaxially to the *triangular process* (*t.p.*), is grooved longitudinally on the inner side, and there is another similar but small grooved articular process postaxially (not shown in Fig. 6). As in the procoxa, there is a long *depressor apodeme* at the apex of the ventrally situated triangular process, and the corium between the peg-like anterior and posterior articular processes is stiff so as to allow insertion of the levator muscles.

The metathoracic trochanter is greatly reduced. It is very narrow preaxially where it is covered over by the femur and is not visible from the outside. At this place it has an articular, preaxial, shallow notch (*n.tr.*) for the blunt anterior limb (*a.l.cox.*) of the dorsal notch of the coxa. It is broad postero-ventrally, where alone it is visible from the outside; at this place it bears the prominent *postaxial articular papillae* (*p.a.p.*) fitting into the pocket at the posterior limb of the dorsal notch of coxa. The pro- and meso-trochanters, on the other hand, are narrow dorsally and broad ventrally on account of the triangular process at their proximal border, where each of them bears preaxially the peg-like articular process. These 2 processes are, however, wanting in the metatrochanter whose

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greatest width is contributed by the projection of its postaxial part along the distal border. The disappearance of the peg-like process is, no doubt, in keeping with the absence of the corresponding articular ventral notch of the coxa and its place has been taken by the preaxial notch (*n.tr.*). Distally, however, the

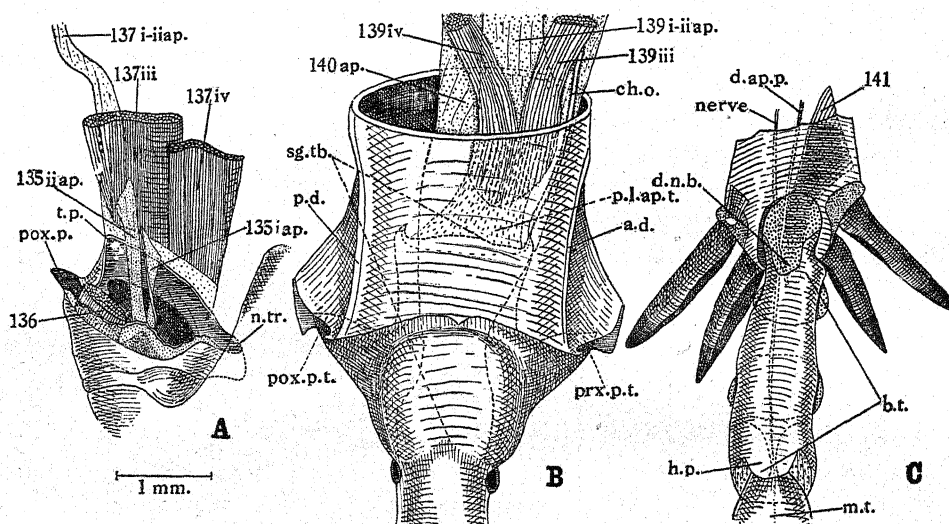


Fig. 7, A-C. *Schistocerca gregaria*, ph. *gregaria*.—A. Right metatrochanter, showing apodemes and muscles together with a little part of the metafemur attached to it. B. Distal part of right metafemur and part of metatibia attached to it. C. Distal part of right metatibia with its spurs and part of metatarsus attached to it.

a.d., antero-dorsal ridge of metafemur; *b.t.*, basal piece of metatarsus; *ch.o.*, chordotonal organ; *d.ap.p.*, depressor apodeme of metapretarsus; *d.xv.b.*, dorsal notch of basal piece of metatarsus; *h.p.*, hood-like process of basal piece of metatarsus; *m.t.*, middle piece of metatarsus; *n.tr.*, preaxial coxo-trochanteral notch of metatrochanter; *p.d.*, postero-dorsal longitudinal ridge of metafemur; *p.l.ap.t.*, posterior levator apodeme of metatibia; *po.x.p.*, postaxial coxo-trochanteral articular papilla of metatrochanter; *po.x.p.t.*, postaxial femoro-tibial articular process; *pr.x.p.t.*, preaxial femoro-tibial articular process; *135 i.ap.*, apodeme of shorter bundle of anterior levator of metatrochanter; *135 ii.ap.*, apodeme of longer bundle of anterior levator of metatrochanter; *136*, posterior levator muscle of metatrochanter; *137 i-ii.ap.*, apodeme of 1st and 2nd scutal bundles of depressor muscle of metatrochanter; *137 iii* and *137 iv*, sternal and coxal bundles of depressor muscle of metatrochanter; *139 i-ii.ap.*, apodeme of 1st and 2nd levator bundles of metatibia; *139 iii* and *139 iv* 3rd and 4th levator bundles of metatibia; *140.ap.*, apodeme of depressor of metatibia; *141*, levator muscle of metatarsus.

metatrochanter shows a preaxial articular notch for articulation with the femur; another articular surface is provided by a small protuberance given out from its dorsal wall, while a third articular place lies postaxially at the base of the distal projection.

The *metafemur* (Fig. 8) is greatly modified in structure and does not resemble the pro- and meso-femora in appearance. It is club-shaped and is considerably broad for about half its proximal length, then narrows down but slightly broadens

again at its distal end. It has, along its anterior and posterior surfaces, a large number of oblique external grooves and their internal ridges ('fish-bones') for the attachment of the levator muscle bundles (139 i) and shows externally 6 longitudinal ridges thus: a *mid-dorsal* (*d.*), a *mid-ventral* (*v.*), an *antero-dorsal* (Fig. 7 B, *a.d.*), an *antero-ventral*, a *postero-dorsal* (*p.d.*) and a *postero-ventral* (*p.v.*). These ridges give the femur a hexagonal appearance in cross-section. The metafemur gives out proximally a large *dorsal process* (*d.p.*) and a small *ventral process* (*v.p.*) leaving a small, deep notch anteriorly and a wide shallow notch posteriorly. The dorsal process covers the trochanter in this region and it does not communicate with the trochanteral cavity on account of a cuticularized *septum* (*sep.*); it is braced by the postero-dorsal, dorsal, the antero-dorsal and antero-ventral ridges; this process is inclined more towards the anterior side, and hence it presents an asymmetrical appearance. The ventral process (*v.p.*) has the ventral (*v.*) and

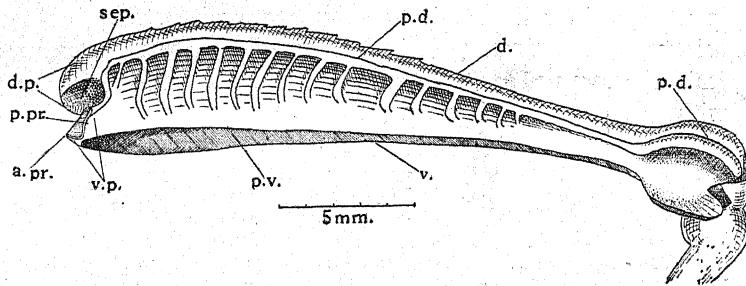


Fig. 8. *Schistocerca gregaria*, ph. *gregaria*.—Posterior view of right metathoracic femur, showing the longitudinal and oblique ridges.

a.pr., trochantero-femoral anterior articular process of metafemur; *d.*, mid-dorsal ridge; *d.p.*, proximal dorsal process of metafemur; *p.d.*, postero-dorsal ridge; *p.pr.*, trochantero-femoral posterior articular process; *p.v.*, postero-ventral ridge; *sep.*, septum of the dorsal process of metafemur; *v.*, mid-ventral ridge; *v.p.*, proximal ventral process of metafemur.

postero-ventral ridges (*p.v.*) and it constitutes the only region which is in communication with the trochanteral cavity and articulates with the trochanter at 3 places, viz., at the large *anterior process* (*a.pr.*), the short *posterior process* (*p.pr.*) and the inconspicuous *dorsal process*; these are strengthened by the antero-ventral, postero-ventral and forward continuations of the dorsal ridges respectively. On account of its articulation with the trochanter at 3 places (as in the pro- and meso-femora), the metafemur largely moves along with the trochanter as if it were part of the latter. Distally, the femur is more strongly cuticularized and is marked into preaxial and postaxial articular thickening; these are strengthened by the antero-dorsal and the postero-dorsal ridges respectively. The thickenings continue downward to articulate with the corresponding areas of the tibia. The invaginated postaxial femoro-tibial process of the pro- and meso-femora is wanting here. The metafemur has, at this end, a broad and deep ventral notch

bordered by the leaf-like lateral expansions (lateral lobes of Karandikar, 1939) between which the tibia can be folded beneath the femur. The corium at the base of the notch is invaginated to give rise to a soft pad (patella of Karandikar, 1939) internally and the notch itself is bridged by a tight femoro-tibial corium which keeps the tibia at right angles to the femur.

The *tibia* of the pro- and meso-thorax resemble each other in having the *sagittate process*, and the *pre-* and *post-articular processes*; the corresponding parts in metatibia are different.

In the *metatibia*, the *sagittate process* (*sg.tb.*) is of enormous size and consists of 3 processes, viz., 2 strongly cuticularized, pointed, and slightly upturned processes, the *pre-* (*prx.p.t.*) and *post-axial articular* (*pox.p.t.*) *processes*, and a broad, rectangular *median process*. The margins of all these processes are bent downward, giving them a concave appearance ventrally. The preaxial and postaxial processes partially lie within and articulate with strongly cuticularized lateral expansions of the femur, while the median process lies completely telescoped within the femur and gives out preaxially a fine tendon-like thread in connection with the chordotonal organ (Slifer, 1935), and internal to it another large, broad, leaf-like *posterior levator apodeme* which, after a short distance, is twisted to become vertical. The part of the sagittate process behind the median process is raised into a large, rounded knob which abuts against the femur when the tibia moves vertically on its pre- and post-axial hinges. Ventrally, the femoro-tibial corium is invaginated near the tibia, forming a large *depressor apodeme*. The tibia bears 2 rows (the outer and inner) of 8-12 spines (exclusive of the spurs mentioned below), which for some distance lie opposite one another, and then irregularly alternate distally; the number of spines in most cases is, however, not the same on the outer and inner sides in the same tibia. The variability in the number of these spines in relation to phase and eye-stripe differences has been studied by Roonwal (1947). Close to its distal end, the tibia bears ventro-laterally 2 large spurs on either side.

The *tarsus* and *pretarsus* of the pterothorax are composed of 3-4 pieces respectively and much resemble those of prothorax, except that the *basal tarsal piece* (*b.t.*) of the metathorax is nearly one-and-a-half times longer than in the pro- and meso-thorax and has deeper *dorsal* (*d.n.b.*) and *ventral notches* at its proximal end, thereby allowing greater flexion of the tarsus dorsally between the dorso-lateral tibial spines. Each of these notches is covered by the tibio-tarsal corium which invaginates to give rise to a short *levator apodeme* in the dorsal notch and long *depressor apodeme* in the ventral notch. The sinuous longitudinal bands of the pro- and meso-tarsi are not visible externally, but the *hood-like projection* (*h.p.*) is present. Ventrally, however, it has only 4 euplantulae or *pulvilli* (*pul.b.*); 2 of these lie one behind the other, and seem to have resulted from the fusion of 2 pulvilli lying side by side in the protarsus; the distal 2 are situated side by side as in the protarsus.

III. MUSCULATURE OF THE MESOTHORAX

1. *Musculature of the Tegmina* (Figs. 2, 4 A-P, 9 and 10 A-B)

Like the trochanter and tibia (Misra, 1947) each tegmen, along with the outer notal part, acts as a lever of the first order in which the pleural wing-process gives support to the second axillary sclerite and acts as the fulcrum, while the outer notal part and the first and second axillary sclerites act as the short arm. The remaining part of the tegmen acts as the long arm which is to be moved like the weight-end of the lever. Power is supplied to the short arm by the two powerful tergo-sternal muscles (85 and 86). The short arm has to work under an obvious mechanical disadvantage which is compensated by the powerful muscles. By this arrangement, maximum speed desirable for the tegmen is produced at the weight-end, although at the cost of greater energy than would have been necessary had the fulcrum been in the centre.

There are 2 categories of tegminal movements and muscles, viz., (a) those producing flight (flight-muscles), and (b) those responsible for folding or flexing and extending the tegmina after and before flight respectively.

(a) FLIGHT-MOVEMENTS AND FLIGHT-MUSCLES

The flight-movements of the tegmina consist of 2 sets, viz., (1) a set of up and down strokes; and (2) a set of forward and rearward movements during the down stroke and up strokes respectively, and an inward torque (twist) at the close of the forward movement. The up and down strokes of the tegmina are produced simply by the depressing and arching of the mesonotum respectively. This movement takes place on 3 hinges provided by the tegminal base on the mesonotal plate, thus: the *first hinge* is formed at the vertical notch of prescutum within which the anterior condyle (*co.*) of the costo-subcostal tegminal sclerite moves; the *second hinge* is at the notal wing-process and the scutal notch (*sct.n.*) on which moves the first axillary tegminal sclerite; and the *third hinge* is provided at the sides of the lateral scutellar lobes on which moves the fourth axillary sclerite.

In order to utilize to the fullest the muscular energy expended in depressing and arching the notal plate, it is necessary that the meso- and meta-notal plates remain immoveable on each other as far as possible, so that no energy is wasted in the movement of one segment on the other. This has been effectively achieved by (i) the fusion of the outer ridge of the mesonotal lateral scutellar lobes (*l.scl.*) with the stiff membrane at the base of the third phragmata; (ii) the attachment of the metanotal alar arm below the fourth mesonotal axillary sclerite; (iii) the stoutly developed metanotal precosta pressing against the mesonotal postnotum; and (iv) the greatly reduced intersegmental membrane between the two plates on either side of the metanotal precosta.

It is believed (Snodgrass, 1930) that in insects the forward and rearward movements of the tegmina depend primarily on the differential response of its anteriorly

situated stiff remigium and posteriorly situated membranous anal and jugal regions to wind pressure below and above it during the down and up strokes respectively. The largest number of veins (C, Sc, R, M, 1 Cu and 2 Cu) are in the remigium where they are crowded together and some of them have even fused to make this part stiff, while the veins in the anal region (1 A, 2 A) are few and far between, and there are none at all in the jugum. These features have made the posterior part of the tegmen membranous and flexible. During the down stroke, therefore, according to Snodgrass (1929a, p. 403), "its posterior part turns upward as a result of the increased pressure below, and this movement gives a forward thrust to the wing, with the result that the anterior margin goes down and forward. For the same reasons the counter strokes have a reverse movement." But the muscles inserted on the basalar mesepipleurite (Figs. 2 and 10), in *Schistocerca gregaria*, at any rate, elaborate these movements and produce an inward twist or torque, thus giving the locust the fine adjustment of its tegmina. There are no muscles for an outward torque, which does not seem to exist apart from the rearward movement.

The *flight-muscles* of the locust may, therefore, be divided into two groups, viz., (1) Muscles producing the up and down strokes; and (2) Muscles producing the inward torque.

(1) *Muscles producing up and down strokes*.—These comprise 6 muscles for each tegmen, as follows:—

(i) *The first tergo-sternal muscle* (Fig. 9, muscle 85) is long and stout (length 9.17 mm.; breadth 2.25 mm.). It arises from the anterior part of the latero-sternite behind the presternal ridge and runs upward and slightly forward to its insertion on the anterior apodeme (Fig. 1 B, *a.ap.*) and its base externally to the longitudinal dorsal muscle (89).

(ii) *The second tergo-sternal muscle* (86) is longer (length 12.15 mm.; breadth 1.62 mm.) than the first. It also arises from the latero-sternite behind the place of origin of the previous muscle and in front of the incomplete horizontal part of furcasternal ridge, runs upward immediately behind, slightly overlapping the previous muscle, and is inserted on the ventral surface of the scutum a little posteriorly and externally to the thinly cuticularized, triangular patch. A small part of this muscle is also inserted on the basal part of the first prong of the notal wing-process.

These two muscles lower the notum by their contraction and, therefore, produce the up stroke of the tegmen.

(iii) *The first oblique dorsal muscle* (87) is very thin and short (length 1.17 mm.; breadth 0.27 mm.). It arises at the junction of the small intersegmental membrane with the precostal rim of the metanotum in front of its anterior phragma and runs forward and slightly upward to its insertion on the rounded, thinly cuticularized patch of the scutum.

(iv) The second oblique dorsal muscle (88) is short and stumpy (length 0.9 mm.; breadth 1.44 mm.) and consists of loosely set fibres originating from the precosta of the metanotum beneath the place of origin of the first oblique muscle. It runs forward and is inserted on the triangular depression (Fig. 1 B) at the crossing of the scuto-scutellar and the reversed notal ridges.

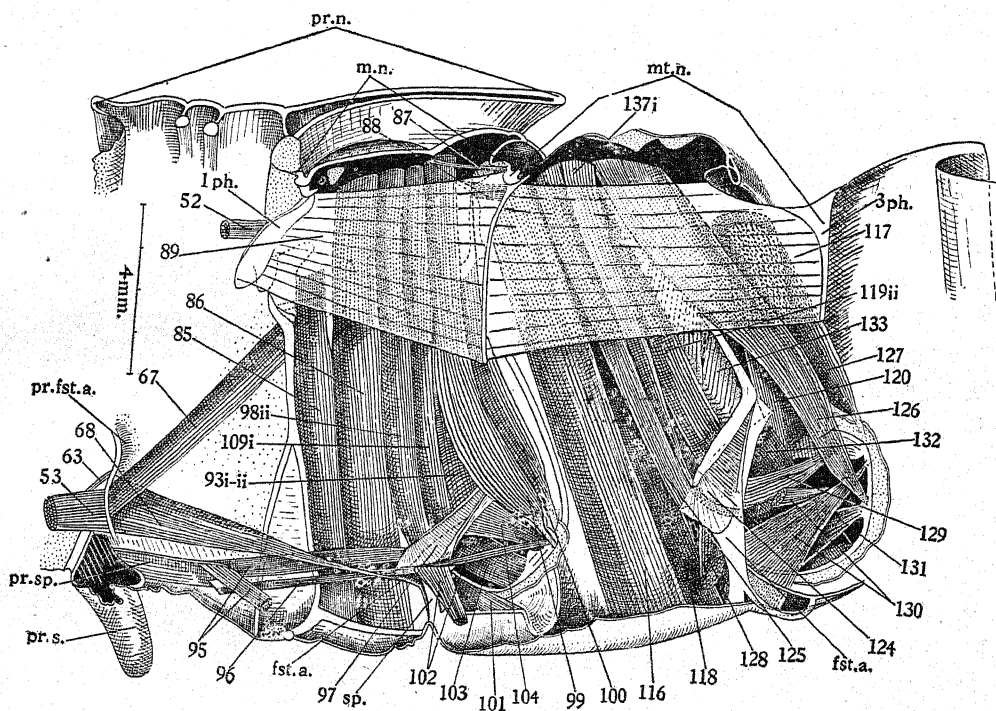


Fig. 9. *Schistocerca gregaria*, ph. *gregaria*.—Meso- and Metapleura (with part of pro-, meso- and metatergum arched over them), showing the muscles. Latero-internal view.

fst.a., furcasternal apophysis; *m.n.*, mesonotum; *mt.n.*, metanotum; *1 ph.*, *3 ph.*, mesothoracic and posterior metathoracic phragmata; *pr.fst.a.*, prothoracic furcasternal apophysis; *pr.n.*, pronotum; *pr.s.*, prosternal spine; *pr.sp.*, prosternal spina; *sp.*, mesosternal spina is 52, dorsal pair of longitudinal muscle of neck; 53, 1st pair of ventral longitudinal muscle of neck; 63, ventral elevator of neck; 67, sterno-pleural intersegmental muscle; 68, 2nd pair of ventral longitudinal muscle; 85, 86, 1st and 2nd tergo-sternal muscle; 89, dorsal longitudinal muscle of tegmen; 93 i, ii, depressor extensor muscle-bundles of tegmen; 95, 96, 3rd and 4th pairs of ventral longitudinal muscles; 97, pleuro-sternal muscle; 98 ii, 2nd bundle of tergal promotor of mesocoxa; 99, 100, 1st and 2nd tergal remotor of mesocoxa; 102, posterior rotator of mesocoxa; 103, 104, 1st and 2nd adductor muscles of mesocoxa; 109 i, scutal bundle of depressor of mesothoracic trochanter; 116, tergo-sternal muscle of metathorax; 117, dorsal longitudinal muscle; 118, 119 ii, 1st and 2nd rotator of wing; 124, depressor extensor of wing; 124, pleuro-sternal muscle of metathorax; 125, tergal promotor of metacoxa; 126, 127, 1st and 2nd tergal remotor of metacoxa; 128, anterior rotator of metacoxa; 129, 130, 1st, 2nd and 3rd posterior rotator of metacoxa; 132, adductor of metacoxa; 133, 1st abductor of metacoxa; 137 i, depressor bundle of metathoracic trochanter.

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These two muscles (87 and 88) supplement the tergosternal muscles by depressing the scutellum and producing the up stroke of the tegmen.

(v) *The dorsal longitudinal muscle* (89) is much stouter (length 5.85 mm.; breadth 4.50 mm.) than the corresponding muscle of the prothorax (Misra, 1947; muscle 52), and is in fact stouter than all the muscles in the head and prothorax (Misra, 1946, 1947); in proportion to its width, it is stumpy. It arises from the entire posterior surface of the mesonotal phragma of its side and spreads out, as it runs backward and slightly upward, to be inserted on the entire anterior face of the anterior metanotal phragma.

This muscle works antagonistically to the previous muscles (85-88) inasmuch as it makes the scutum more convex by its contraction, thereby producing a down stroke of the tegmen. But, since the place of insertion of this muscle is separated by a narrow intersegmental membrane from the plate on which its place of origin lies, the effect of the contraction of the muscle is more pronounced near the latter region, *i.e.*, the scutum (which gives articulation to the remigium of the tegmen).

(vi) *The tergo-pleural dorsal muscle* (Fig. 10; muscle 90) is short, stumpy and very stout (length 1.98 mm.; breadth 2.25 mm.). It arises from the pleural ridge of the pleural wing-process dorsally and anteriorly to the place of origin of the flexor of the tegmen (94), runs in a straight line externally to the first and second rotator muscles of the tergum (91 and 92) and is inserted on the entire posterior face of the posterior apodeme (*p.ap.*) of the prescutum.

This powerful muscle arches the prescutum which gives articulation to the costo-subcostal sclerite (Fig. 4 A, *C.Sc.s.*) of the tegmen and thereby produces its down stroke. By pulling the costo-subcostal sclerite at its inner condyle (*co.₁*), this muscle possibly also bends the anterior part of the tegmen and may help in its inward torque.

The first and second tergo-sternal muscles (85 and 86) of *Schistocerca gregaria* correspond in origin and insertion to muscles of the same name in *Dociostaurus maroccanus* (Jannone, 1940) and *Dissosteira carolina* (Snodgrass, 1929). The first muscle (85) corresponds to a similar muscle of *Anacridium aegyptium* (Berlese, 1909); the latter author has neither figured nor described the second tergo-sternal muscle (86). The first oblique dorsal muscle (87) of *S. gregaria* corresponds in origin and insertion to the oblique dorsal muscle of *Dissosteira carolina* and has not been mentioned by Berlese (1909) in *A. aegyptium* or by Jannone (1940) in *Dociostaurus maroccanus*. *S. gregaria* has a second extra pair of oblique dorsal muscles (88) which appears to be absent in *A. aegyptium*, *Dissosteira carolina* and *Dociostaurus maroccanus*. The dorsal longitudinal muscle (89) of *S. gregaria* is homologous with the second mesonotal muscle of *Anacridium aegyptium* (Berlese, 1909) and with the longitudinal dorsal muscle of *Dissosteira carolina* and *Dociostaurus maroccanus* because of the similarity of origins and insertions. *S. gregaria* has an additional muscle, *viz.*, the tergo-pleural muscle (90) which has been noted only by La Greca (1947) in *Anacridium aegyptium* where it has similar origin and insertion although it is considerably thinner. This muscle has not been noted by Snodgrass (1929) in *Dissosteira carolina* and Jannone (1940) in *Dociostaurus maroccanus*.

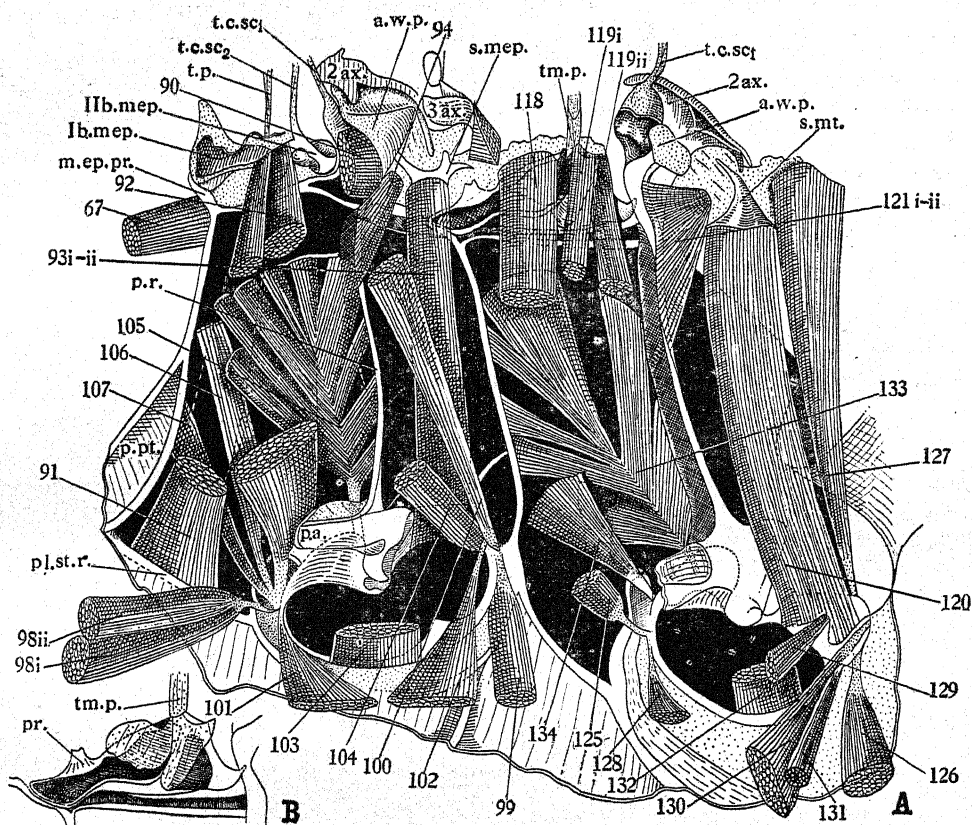


Fig. 10, A-B. *Schistocerca gregaria*, ph. *gregaria*.—Meso- and metapleura and associated parts of sterna and the axillary sclerites, showing the muscles. Latero-internal view. A. Mesopleuron. B. Metapleuron.

a.w.p., articular lobe of pleural wing-process; *2 ax.*, *3 ax.*, 2nd and 3rd axillary sclerites; **I-II** *b.mep.*, 1st and 2nd basalar mesepipleurites; *m.ep.pr.*, mesepisternal process; *p.a.*, pleural apophysis (partly cut off); *pl.st.r.*, pleuro-sternal ridge; *p.pt.*, prepectus; *pr.*, sucker-shaped process of 1st basalar metepipleurite; *s.mep.*, subalar mesepipleurite; *s.mt.*, subalar metepipleurite; *t.c.sc.*₁, tendon joining wing-process with costo-subcosta; *t.c.sc.*, tendon joining 2nd basalar mesepipleurite with the costo-subcosta at the nodule; *tm.p.*, tendinous membrane connecting 2nd basalar metepipleurite with the precosta of wing; *t.p.*, tendon connecting 1st basalar mesepipleurite with the precosta of tegmen; **67**, sterno-pleural intersegmental muscle; **90**, tergo-pleural dorsal muscle; **91, 92**, 1st and 2nd rotator muscles of tegmen; **94**, flexor of tegmen; **98 i, ii**, tergal promotor bundles of mesocoxa; **99**, 1st tergal remotor of mesocoxa; **101**, anterior rotator of mesocoxa; **102**, posterior rotator of mesocoxa; **103, 104**, 1st and 2nd adductor muscles of mesocoxa; **105, 106, 107**, 1st, 2nd and 3rd abductor muscles of mesocoxa; **118, 119 i-ii**, 1st and 2nd rotator muscles of wing; **120**, depressor extensor of wing; **121 i-ii**, the two flexor muscle-bundles of wing; **125**, tergal promotor of metacoxa; **126, 127**, 1st and 2nd tergal remotors of metacoxa; **128**, anterior rotator of metacoxa; **129, 130, 131**, 1st, 2nd and 3rd posterior rotators of metacoxa; **132**, adductor of metacoxa; **133, 134**, 1st and 2nd abductors of metacoxa.

(2) *Muscles producing twist or rotation of the tegmen.*—These comprise 2 muscles for each tegmen as follows:—

(i) *The first rotator of tegmen* (91) is a long and stout muscle (length 8.37 mm.; breadth 2.16 mm.). It arises from the precoxal bridge externally to the place of origin of tergosternal muscle of its side (85) and runs upward and slightly forward to its insertion on the anterior part of the ventral disc-like process of the first basalar epipleurite.

(ii) *The second rotator of tegmen* (92) is also a long muscle (length 8.82 mm.; breadth 1.53 mm.) but is thinner than the first. It lies externally to and alongside the latter muscle (91) and arises in part from the second abductor and largely from its own small tendon-like apodeme of the mesocoxa (Fig. 6 C, II *r.t.ap.*) internally to the place of insertion of the second abductor muscle of the coxa. It runs upward to and is inserted on the posterior part of the disc of the first basalar epipleurite.

These 2 muscles pull the two basalar mesepipleurites downward and inward. Since the tegminal precostal plate (*Pc.*) and the base of costo-subcostal vein are connected with the mesepipleurites by tendons (Fig. 2), the pull on them gives the anterior part of the tegmen an inward twist or rotation at the end of the downward stroke; as already stated, the tergo-pleural dorsal muscle possibly also helps in this action.

Snodgrass (1929) has called the inward twist or rotation of the tegmen about its long axis as '*pronation*', thereby homologizing it with the movements of the radio-ulnar joints of the vertebrate fore-limb. According to Johnston & Whillis (1946, p. 484), "the movements which take place at the radio-ulnar joints result in pronation and supination of the hand. In pronation the radius, carrying the hand with it, is carried obliquely across the front of the ulna, its upper end remaining lateral, and its lower end becoming medial, to that bone. In supination the movement is reversed and the radius lies lateral to and parallel with the ulna". The term pronation, being in this manner mainly restricted to the inward movement of the human or vertebrate palm alone, is ill suited for the inward twist or rotation of the insect tegmen. Again, this expression is inapplicable in the present context because the counterpart of this movement, viz., the outward twist, does not appear to be a distinct result of any antagonistic muscles (supinator muscle). Furthermore, since the tegmina and the wings cannot be compared to the radio-ulna of the vertebrate fore-limb, the comparison of inter-articular movement of the tegmen (which will only result in flexion or rotation and not in pronation and supination) with the movements of radio-ulnar joint is inadequate. The outward twist of the tegmina is due purely to the differential effect of wind pressure above.

The first and the second rotator muscles (91 and 92) of *Schistocerca gregaria* correspond, in origin as well as insertion, to the first and second pronator extensor muscles of *Dissosteira carolina* (Snodgrass, 1929) and *Dociostaurus maroccanus* (Jannone, 1940).

(b) FLEXION AND EXTENSION OF TEGMINA AND MUSCLES RESPONSIBLE FOR THEM

Flexion and extension were studied in spirit-preserved specimens of the Desert Locust by pulling the tegmen at right angles to the longitudinal axis of the locust and flexing them to their normal position of flexion, and also by noting the movements of the sclerites on one another. The following movements were observed (Fig. 4 A-P):—

(1) The precosta of the tegmen (*Pc.*) moves in an arc backward and slightly upward; (2) the inner condyle (*co.*) of the costo-subcostal sclerite slides forward within the vertical notch of the prescutum, and the distal end of the sclerite describes an arc of a circle backward and then finally slightly upward; (3) the first axillary sclerite becomes vertical so that its proximal margin points downward; (4) the anterior margin of the distal median sclerite at its fusion with the outer process of the second sclerite is easily flexible and describes an arc along with the radial vein backward and slightly upward so that its outer margin dips down. This movement of the median sclerite makes the basal fold convex, pushes the outer margin of the proximal sclerite backward, upward and inward, thereby folding the entire sclerite beneath the distal and making it stand vertically on its articulation with the second axillary sclerite. (5) The outer basal part of the first anal vein, being fused with the outer posterior margin of the distal sclerite, swings downward; its proximal end, which is fused behind the outer end of the third sclerite, moves upward, thus revolving the latter sclerite upward and making it vertical. The third axillary sclerite is partly made to revolve passively by the arc-like movement of the two median accessory sclerites and the base of the first anal vein and largely by the downward pull exercised by the flexor muscle (94) on the inner process and the forward pull on the ventral ridge through the depressor extensor muscle (93) inserted on the suralar mesepipleurite. (6) At this stage the jugum no longer remains taut and is deflected along its jugal fold. (7) The anterior inner process and the proximal end of the third axillary sclerite sinks down. These movements can be readily understood in relation to the following two muscles:—

(i) *The depressor extensor of the tegmen* (93 i and ii) consists of two long and stout muscle bundles. The first bundle (length 7.20 mm.; breadth 1.17 mm., 93 i) arises from the epimeral basicosta closely behind the pleural articulation, while the second (length 6.75 mm.; breadth 1.08 mm., 93 ii) arises from its apodeme behind the place of origin of the first (Fig. 6 C). The two bundles run close together and are inserted ventrally at the base of the subalar epipleurite immediately beneath its anterior limb.

(ii) *The flexor of the tegmen* (94) is a short and stout fan-shaped muscle (length of the largest fibres 3.15 mm.; maximum breadth 0.94 mm.). It arises with a broad base from the inner edge of the upper part of the pleural ridge and a part of its wing-process, runs upward and backward closely in front of the depressor extensor (93), and is inserted ventrally at the inner anterior process of the third axillary sclerite.

On account of the insertion of the depressor extensor muscle (93 i, ii) being removed anteriorly to the central part of the subalar epipleurite, the pull of the muscle moves the sclerite in an arc backward, the anterior limb of the sclerite which is directly above the insertion of the muscle is pulled downward and the forked posterior limb is pushed upward. Considering the connections of these anterior and posterior limbs with the second and third axillary sclerite (Figs. 4 E, G)

and that of these two sclerites with the proximal median one, the relative action of the muscle on them can be followed. The posterior end of the ventral ridge of the second sclerite is slightly raised upward and the outer process of the sclerite, the inner end of the radial vein and the outer margin of the distal median sclerite are flexed downward. As a result of this, the basal fold between the two median sclerites becomes more convex, the outer end of the proximal rises up and its inner margin flexes downward; all these movements make it vertical to the second sclerite. As the proximal median sclerite bends upward on the second sclerite and the distal one bends downward on the proximal, the outer end of the third sclerite revolves upward. This movement of the third sclerite is intensified by the contraction of the flexor of the tegmen (94) which pulls the anterior inner process (*i.p.*) downward, till the outer end of the third sclerite revolves upward, then inward, and finally comes to lie laterally on the scutum. The joint of the third sclerite with the first anal vein is very flexible and readily allows the anal vein to revolve backward; the jugum no longer remains taut and flexes at its fold and comes to lie below the anal area when the tegmen has completely flexed. The vertical movement of the first axillary sclerite is largely facilitated by the tendinous membrane at its proximal articulations with the mesonotum.

It appears very probable that the axillary bundle of the depressor muscle of the trochanter (109 ii), which is attached on this sclerite ventrally, helps the first axillary sclerite in the vertical movement just before the flexion of the tegmen is completed.

The depressor extensor of the tegmen (93 i and ii) of *Schistocerca gregaria* corresponds, both in origin and insertion, to a similar muscle of *Dissosteira carolina* (Snodgrass, 1929) and *Dociostaurus maroccanus* (Jannone, 1940), with this difference that while the muscle in *S. gregaria* has 2 bundles of fibres, one of which (93 i) arises directly from the epimeral region of the basicosta of coxa and the other (93 ii) from the same region but through a tendon, the muscle in the other two Acridiids arise directly from the flat basicosta itself. The flexor of the tegmen (94) of *S. gregaria* corresponds, both in origin and insertion, to the flexor muscle of the axillary sclerite of *Anacridium aegyptium* (La Greca, 1947) and the pleuro-alar or flexor of the fore-wing of *Dissosteira carolina* and *Dociostaurus maroccanus*:

2. Musculature in Relation to Movements of Mesothorax (Figs. 3 B and 9)

This consists of 2 pairs of ventral-longitudinal and sterno-pleural muscles as follows:—

(i) *The third pair of ventral-longitudinal muscles* (95) is long and slender (length 3.78 mm.; breadth 0.72 mm.) and arises from the anterior part of the shelf-like furcasternal apophysis above the apodeme of the second pair of ventral longitudinal muscle (68; Misra, 1947). It crosses the above apodeme diagonally inward and forward, and is inserted externally on the posterior part of the prothoracic spinasternal spine (Fig. 9, *pr.sp.*).

(ii) *The fourth pair of ventral longitudinal muscles* (96) is also long but is more slender (length 3.60 mm.; breadth 0.18 mm.) than the previous pair. It arises from the anterior scopped part of the spinasternal spine, runs forward

in a straight line between the third pair of muscles (95) and is inserted on the prothoracic spinasternite behind and at the base of its spine (Fig. 9).

For the greater part of their course, these muscles (95 and 96) are situated within the pterothoracic sternum which is compact and acts as one piece (called plastron); hence it is heavier than the prothoracic sternum. It seems more likely that they move the prothoracic sternum on the pterothoracic sternum, rather than the other way about.

(iii) *The sterno-pleural muscle* (97) is very short but close-set, extensive and thick (length 0.63 mm.; breadth 3.24 mm.). It connects the two anterior and posterior surfaces of the upper ridges of the pleural apophysis of its side with the inner walls of the shelf-like sternal apophysis.

But for the joint between the pleural and sternal apophyses through the sterno-pleural muscles (97), the pleural and sternal regions of the mesothorax are fused together. It appears that these muscles bring the pleural and sternal walls somewhat closer together, thereby reducing the capacity of the thoracic cavity. The original capacity of the mesothoracic cavity is restored by the elasticity of the pleural walls and relaxation of the sterno-pleural muscles. Whether these movements of the pleural walls affecting the capacity of the thoracic cavity also indirectly compress and relax the tracheal sacs for respiration in a way similar to those of the prothorax [caused by the ventral elevators of the neck (63) and the sterno-spinal muscles 69; Misra, 1947] can be ascertained with certainty only after the position of tracheal sacs has been studied. These muscles however, do not appear to be homologous with the two muscles of the prothorax.

The third and the fourth pairs of ventral longitudinal muscles (95 and 96) and the sterno-pleural muscles (97) of *Schistocerca gregaria* correspond, in origin and insertion, to similar muscles of *Dissosteira carolina* (Snodgrass, 1929) and *Dociostaurus maroccanus* (Jannone, 1940). The last mentioned muscle, as far as is evident from Berlese's (1909) figures, corresponds in origin and insertion to the lateral muscle of the fork (*forca*) of mesothorax in *Anacridium aegyptium*.

3. Musculature of the Mesothoracic Legs (Figs. 3 B, 9 and 10 A-B)

(a) MUSCLES OF BASIPODITE

These comprise 10 muscles which arise from different places on the notal, pleural and sternal regions and are as follows:—

(i) *The tergal promotor of coxa* (98 i, ii) consists of 2 bundles of long and stout muscle-fibres one of which is shorter than the other. The shorter bundle (98 i, length 8.28 mm.; breadth 0.90 mm.) lies externally to the other one and arises ventrally from the basal part of the notal wing-process where it lies internally to the tergo-pleural dorsal muscle (90), while the longer bundle (98 ii, length 11.07 mm.; breadth 1.35 mm.) also arises ventrally from the scutum near the base of the notal wing-process. Both the bundles run downward, to be inserted together on the tergal promotor apodeme,

This muscle moves the mesothoracic leg forward by its contraction.

(ii) *The first tergal remotor of coxa* (99) is a long and stout muscle (length 9.9 mm.; breadth 1.17 mm.) which originates from the scutum in front of and externally to the scuto-scutellar ridge and runs down to its insertion on its own apodeme.

(iii) *The second tergal remotor of coxa* (100) is shorter and thinner (length 5.67 mm.; breadth 0.81 mm.) than the first. It arises from the outer margin of the scutal process (Figs. 1 A and B, *sct.p.*) and runs downward to its insertion on its long apodeme at the posterior angle of the coxal base.

These two muscles (99 and 100) work antagonistically to the promotor muscle (98 i, ii) and pull the leg backward.

(iv) *The anterior rotator of coxa* (101) is a short and stout muscle (length 3.3 mm.; breadth 1.8 mm.) which, at its origin, is triangular in cross-section. It arises externally from the entire ridge of the furcasternal lobe of the mesosternum (Figs. 3 B and 9) and runs forward and outward to its insertion on its apodeme at the anterior and inner corner of the coxal base.

(v) *The posterior rotator of coxa* (102) is shorter and thinner (length 4.05 mm.; breadth 1.35 mm.) than the anterior rotator (101). It arises from the lateral side of the top of the spina (Fig. 3 B) and crosses the anterior rotator diagonally as it runs outward and backward to its insertion (Fig. 10 A) on its apodeme on the posterior and outer corner of the coxal base behind and internally to the attachment of the first tergal remotor apodeme (Fig. 6 C, *I t.r.ap.*) on the coxal base. This muscle, on account of its insertion on the outer margin of the coxal base, works antagonistically to the anterior rotator muscle and twists the leg outward.

(vi) *The first adductor of coxa* (103) is a short and stout muscle (length 1.03 mm.; breadth 1.80 mm.) which arises from the posterior surface of the mesosternal apophysis (Fig. 9), lies anteriorly to the posterior rotator muscle and runs outward to its insertion on the broad, ventral (inner) part of the basicosta (Fig. 10 A).

This muscle pulls the leg mesially inward, *i.e.*, towards the leg of the opposite side.

(vii) *The second adductor of coxa* (104) is also stout (length 1.8 mm.; breadth 1.44 mm.), but is longer than the previous muscle. It arises from the outer posterior surface of the mesosternal apophysis close to the origin of the previous muscle (103) and runs outward to its insertion on the posterior part of the broad epimeral basicosta between the places of insertion of the second tergal remotor (100) and the posterior rotator muscle (102).

This muscle works together with the first (103) and brings the two opposite legs together.

(viii) *The first abductor of coxa* (Fig. 10 A, muscle 105) is a large, fan-shaped muscle (length 5.85 mm.; breadth 2.7 mm.). It arises from the horizontal

ridge of the episternum and the lower part of anterior face of the pleural ridge, and is inserted, by means of its strong tendon-like apodeme, dorsally on the external protuberance of coxa anteriorly to its pleural articulation.

(ix and x) *The second and third abductors of coxa* (Fig. 10 A; muscles 106 and 107) are respectively large (106, length 4.86 mm.; breadth 1.35 mm.) and small (107, length 4.14 mm.; breadth 0.90 mm.). They are fan-shaped and lie externally to the second rotator of the tegmen (92). The small muscle (107) lies in front of the larger one but is contiguous with it and the two remain indistinguishable from each other during their course. They are, therefore, clearly separable only near their places of insertion. The larger muscle (106) arises obliquely from the infraepisternum above the place of origin of the other muscle (107) which arises from the posterior ridge of the prepectus. Both the muscles converge as they run downward and backward to be inserted on their respective apodemes which are long.

These powerful muscles, being inserted on the dorsal (outer) rim of the coxa, pull the legs wide apart.

The tergal promotor of coxa (98 i, ii) of *Schistocerca gregaria* corresponds in origin and insertion to the first dorso-ventral subcostal muscle of the mesothorax of *Anacridium aegyptium* (Berlese, 1909, as far as is evident from his figures), to the tergal promotor of coxa of *Dissosteira carolina* (Snodgrass, 1929) and to the tergal protractor of the second pair of coxa of *Dociostaurus maroccanus* (Jannone, 1940). The only difference between *S. gregaria* and the other Acridiids is that while the former has two bundles of muscle fibres, the latter have only one. The first and second tergal removers (99, 100), the anterior and posterior rotators (101, 102) and the first and second adductors (103, 104) of the coxa of *S. gregaria* correspond, in origin and insertion, to similar muscles of *Dissosteira carolina* and *Dociostaurus maroccanus*. The first, second and third abductors of the coxa of *S. gregaria* correspond to the third, second and first abductors of *Dissosteira carolina* and *Dociostaurus maroccanus*.

There is some discrepancy in the nomenclature of these 3 muscles in Snodgrass's (1929) and Jannone's (1940) accounts which becomes apparent on comparing the origins and insertions of the abductors in the pro-, meso- and meta-coxae of the two authors. They have given different names to the muscles having similar places of origin and insertion in the 3 coxae of the Acridiids studied by them. The only abductor of the procoxa, the third abductor of the mesocoxa and the second abductor of metacoxa have similar origins, so that they must be regarded as homologous. Likewise, the first abductor of the meso- and meta-coxae are homologous because they have similar origins and insertions.

As the meso- and meta-thoracic legs have become modified in response to the requirements of flight of the locust, two (in mesocoxae) and one (in metacoxae) extra abductors have been added to them over and above the one of procoxa which is required for pure and simple abduction of the legs themselves. It seems, therefore, proper to regard the abductor muscle of the procoxa and the corresponding muscles of meso- and meta-coxae as the original first, and count the other two muscles of the mesocoxa serially as the second and third. On this criterion, the procoxa has only the first abductor, the mesocoxa the first, the second and the third, and the meta-coxa only the first and the second.

(b) MUSCLES OF TELOPODITE (Figs. 4, C and 9)

Muscles 108, 109 iii-v, 110, 112, 113, 114, 115 i-iii, being similar to corresponding prothoracic muscles, have not been figured.

These 7 muscles move the different segments of the telopodite of the legs and are as follows:—

(i) *The levator of the trochanter* (108 i, ii) consists of 2 stout bundles—a small one lying in front of a larger one. The small muscle-bundle (length 1.8 mm.; breadth 1.35 mm.) arises from the distal surface of the epimeral basicosta, and the larger bundle (length 2.25 mm.; breadth 1.53 mm.) from the posterior angle of the basicosta. Both of them run outward and are inserted dorsally on the trochanteral ridge, the small one lying medially and the large one just behind it and in front of its postaxial articulation with the coxa.

(ii) *The depressor of the trochanter* (109 i–v) consists of 5 bundles which resemble the corresponding bundles of the prothoracic trochanter. Two of them are coxal and three mesothoracic, since their places of origin are situated respectively in the coxa and mesothorax. The mesothoracic bundles comprise the following:—

(a) *The scutal bundle* (Fig. 9; muscle 109 i) is long and stout (length 10.35 mm.; breadth 0.9 mm.). It arises laterally from the scutum behind the place of origin of the long tergal promotor (109 ii), runs vertically downward parallel to it, in front of the pleural arm, and is inserted on the depressor apodeme of the trochanter.

(b) *The axillary bundle* (109 ii) is shorter but of the same width (length 9.27 mm.; breadth 0.9 mm.) as the scutal bundle and arises vertically from the proximal part of the first axillary sclerite of the tegmen (Fig. 4 C; muscle 109 ii). At this place it lies just internal to the tergo-pleural dorsal muscle (90), and all along its course it lies below the scutal bundle (109 i). It runs almost vertically downward externally to the tergal promotor muscle bundles (98 i, ii) and in front of the pleural arm, and is inserted on the depressor apodeme externally to the place of insertion of the scutal bundle.

(c) *The sternal bundle* (109 iii) is short, stout and fan-shaped (length 3.6 mm.; maximum breadth 1.8 mm.). It arises from the ventral and anterior surfaces of the shelf of the sternal apophysis and lies externally to the first and second adductor muscles (103, 104). It runs outward and downward and is inserted at the base of the depressor apodeme internally to the other two mesothoracic bundles above the place of insertion of the anterior and posterior coxal bundles of the depressor muscle.

The coxal bundles are as follows:—

(d) *The anterior bundles* (109 iv) are 2 in number (each bundle of length 1.35 mm.; breadth 0.9 mm.). They arise distally from the broadened episternal basicosta, run outward and are inserted one behind the other—one on the trochanteral ridge on the anterior slope of the ventral process and the other at the base of the large depressor apodeme externally to the mesothoracic bundles but obliquely disposed to the posterior bundles.

(e) *The posterior bundles* (109 v) are also 2 in number (length 1.62 mm.; breadth of both 1.35 mm.). They arise distally from the ventral broadened part of the basicosta just posterior and opposite to the place of insertion of the first adductor muscle (103). They run outward and are inserted one behind the other on the trochanteral ridge—one on a small separate apodeme on the posterior slope of the ventral process and the other at the base of the large apodeme externally to the mesothoracic bundles of the depressor muscle.

(iii) *The depressor of tibia* (110) is a long and stout muscle (length 1.35 mm.; breadth 0.45 mm.), the greater part of which arises from the ventrolateral wall of the femur. One bundle of this muscle arises ventrally from the trochanteral ridge opposite the place of insertion of the depressor apodeme of the trochanter. These bundles are inserted in a pinnate manner on the depressor apodeme.

A long, slender tendon-like thread arises antero-dorsally from the trochanteral ridge in the form of a knob; it runs outward along the length of the mesofemur closely parallel to the nerve of the leg and is inserted distally on the preaxial surface of the sagittate process. As this tendon-like thread is connected with the nerve at the knob and also further away from it, and does not show any muscle fibres in the stained whole mount, it appears to be a femoral *chordotonal organ* similar to that described by Slifer (1935) in *Melanoplus differentialis* Uhl. (Acridiidae) rather than the anterior levator muscle as described by Snodgrass (1929) and Jannone (1940).

(iv) *The posterior levator muscle of tibia* (112) is almost as long as the depressor muscle (length 8.10 mm.; breadth 0.45 mm.). It consists of several bundles which arise postero-ventrally from the entire length of the femur and are inserted in a pinnate fashion on its apodeme.

(v) *The levator of tarsus* (113) is a short, stout and triangular muscle (length 4.50 mm.; maximum breadth 0.45 mm.), which arises antero-laterally from the distal part of the tibia and is inserted on the levator apodeme in the dorsal notch of the tarsus.

(vi) *The depressor of tarsus* (114) is larger (length 4.50 mm.; breadth 0.90 mm.) than the levator and consists of several bundles. It arises ventro-laterally from the distal half of the tibia and is inserted on its apodeme in a pinnate fashion on the ventral notch of the tibia.

(vii) *The depressor of pretarsus* (115 i-iii) consists of three bundles as in the prothoracic leg. These are as follows:—

(a) *The femoral bundle* (115 i) is the largest (length 6.75 mm.; breadth 0.36 mm.) of all. It consists of 2 compact bundles which arise dorsally from the femoral ridge just posteriorly to the place of origin of the anterior levator of tibia and is inserted on the long depressor apodeme.

(b) *The first tibial bundle* (115 ii) is long and slender (length 2.70 mm.; breadth 0.36 mm.) and also consists of 2 bundles which arise dorsally from the apex of the sagittate process of the tibia and are inserted on the long depressor apodeme.

(c) *The second tibial bundle* (115 iii) again is as long and slender (length 2.70 mm.; breadth 0.36 mm.) as the previous muscle bundle and consists of 2 bundles which arise postero-ventrally from the tibia at the base of its sagittate process. They are contiguous with the distal part of the first bundle and are inserted on the depressor apodeme.

The levator and depressor muscles of the trochanter (108 i, ii and 109 i-v) of *Schistocerca gregaria* correspond, in origin, insertion and in the number of bundles that each muscle possesses, to similar muscles of *Dissosteira carolina* (Snodgrass, 1929), and *Dociostaurus maroccanus* (Jannone, 1940). I have not been able to find the reductor muscle of the mesofemur in *S. gregaria*; this muscle has been found in the 2 other Acridiids mentioned above. The depressor of tibia (110), the posterior levator of tibia (112); the levator (113) and depressor (114) muscles of tarsus, and the depressor of pretarsus (115 i-iii) of *S. gregaria*, all correspond in origin and insertion to similar muscles of *Dissosteira carolina* and *Dociostaurus maroccanus*.

IV. MUSCULATURE OF THE METATHORAX

1. *Musculature of the Wings* (Figs. 9 and 10 A, B)

(a) MUSCLES PRODUCING THE UP AND DOWN STROKES OF WINGS

These wing-muscles are only 2 in number as against 6 of the tegmen. The oblique dorsal muscle and the tergo-pleural muscles are altogether absent here. The absence of the last mentioned muscle is in keeping with the comparatively poorly developed pleural ridge in the region of the notal wing-process and the greatly reduced prescutum. There is, however, only one tergo-sternal muscle here as against 2 of mesothorax. The 2 wing-muscles are as follows:—

(i) *The tergo-sternal muscle* (116) is long and stout (length 11.7 mm.; breadth 0.90 mm.). It arises from the posterior metabasisternum (Figs. 3 A, B; *mt.bst.*) behind its ridge or suture (*s.mt.*), runs vertically upward in front of the scutal bundle of the depressor of the trochanter and is inserted at the base of anterior phragma and part of the proximal prescutum.

This muscle, by its contraction, lowers the metanotum, thereby producing the up stroke of the wing.

(ii) *The dorsal longitudinal muscle* (117) is large and very powerful (length 8.55 mm.; breadth 9.0 mm.) and extends between the anterior and posterior phragmata of the metanotum. A large part of this muscle is attached directly on the postnotal plate itself, a small part is attached on it through a tendon-like apodeme and the remainder on the posterior phragma.

This muscle works antagonistically to the previous muscle (116), arches the metanotum and produces the down stroke of the wing.

The tergo-sternal (116) and the dorsal longitudinal muscles (117) of *Schistocerca gregaria* correspond, both in origin and insertion, to the tergo-sternal and longitudinal dorsal muscles of *Anacridium aegyptium* (Berlese, 1909), *Dissosteira carolina* (Snodgrass, 1929) and *Dociostaurus maroccanus* (Jannone, 1940).

(b) MUSCLES TWISTING OR ROTATING THE WING INWARD

These consist of 2 well developed muscles of which the second is the more developed, a feature which is in keeping with the greater development of the apodeme of the second basalar metepipleurite (Fig. 10 B) on which it arises. These muscles are as follows:—

(i) *The first rotator of wing* (118) is a longer and stouter muscle (length 11.25 mm.; breadth 3.14 mm.) than its counterpart of the tegmen. It arises from the outer posterior part of the metabasisternum (*mt.bst.*), runs vertically upward and slightly outward behind the tergosternal muscle (116) and is inserted on the disc-shaped apodeme (Fig. 10 B) of the first metepipleurite.

(ii) *The second rotator of wing* (119 i, ii) consists of 2 muscle-bundles. One bundle (119 i; length 9.36 mm.; breadth 1.08 mm.) is slender and arises from the outer posterior part of metabasisternum just behind the place of origin of the first rotator of the wing (118) with which the muscle remains contiguous for some part of its course; it runs upward and slightly forward and is inserted on the disc-shaped apodeme of the second basalar metepipleurite. The second or stouter bundle (119 ii; length 9.36 mm.; breadth 1.46 mm.) arises from second abductor apodeme and the dorsal anterior basicosta of the metacoxa, runs upward and slightly forward towards its fellow bundle (119 i) and is inserted jointly with it on the basalar metepipleurite.

The first and the second rotator muscles of the wing (118, 119, i, ii) of *Schistocerca gregaria* correspond, in origin and insertion, to first and second pronator extensor muscles of the wing of *Dissosteira carolina* (Snodgrass, 1929). They have not been described in *Dociostaurus maroccanus* (Jannone, 1940) and *Anacridium aegyptium* (La Greca, 1947).

(c) MUSCLES PRODUCING FLEXION AND EXTENSION OF THE WING

These consist of 2 muscles like those of the tegmen, but of these two, the flexor of the wing presents a much more elaborate arrangement for revolving the third axillary sclerite, thereby closing the larger wings. These 2 muscles are as follows:—

(i) *The depressor extensor of wing* (120) is a short, stout and compact muscle (length 7.20 mm.; breadth 2.88 mm.) which arises from the entire dorsal posterior part of the metacoxal basicosta and runs upward in front of the second tergal remotor muscle (127) to its insertion on the base of subalar metepipleurite.

(ii) *The flexor of wing* (121) consists of two compact fan-shaped bundles—a small and a large one. The small bundle (length 1.08 mm.; breadth 1.98 mm.) arises from the posterior face of the pleural ridge, just short of its continuance into the pleural wing-process. The larger bundle (length 4.05 mm.; breadth 3.60 mm.) also arises from the same ridge but internally to the place of origin of the small bundle; it has a larger expanse at this place than the smaller bundle. These 2 bundles cross each other diagonally—the small one outside the large one—and are inserted ventrally at the inner process (Fig. 4 P, *i.p.*) of the third axillary sclerite at two places very near each other.

These 2 muscles (120, 121) correspond to similar muscles of *Dissosteira carolina* (Snodgrass, 1929); the latter muscle (121) of *S. gregaria*, however, differs from that of *D. carolina* in this respect that the muscle is more elaborate and has 2 bundles crossing each other during their course and insertion, whereas in *D. carolina* it consists of only one bundle.

2. Musculature in Relation to Movements of Metathorax (Fig. 3 B)

The following 3 muscles are found in relation to meso- and metathorax :—

(i) *The fifth pair of ventral longitudinal muscle* (122) is a thin, sclerotized thread showing no muscle-fibres at all. One end of this thread is attached on the anterior angle of the metasternal apophysis while the other end is seen lying free in the body-cavity.

(ii) *The sixth pair of ventral longitudinal muscle* (123) is long and very slender (length 3.6 mm.; breadth 6.09 mm.). It arises from the posterior part of mesosternal spina behind the place of origin of the posterior rotator of the mesocoxa (102), runs backward and outward and is inserted on the anterior angle of the metasternal apophysis.

(iii) *The sterno-pleural muscle* (124) is very short, close-set and extensive (length 0.63 mm.; breadth 3.15 mm.) and serves to connect the two anterior and posterior surfaces of the upper ridges of pleural apophysis with the inner walls of the shelf-like metasternal apophysis.

As the sternal and pleural regions of the meso- and meta-thorax are fused together, the scope of movement between these 2 segments is limited to what is permissible by the elasticity of the chitin. The longitudinal muscles (122, 123), therefore, are greatly reduced, the fifth pair (122) having been reduced to a defunct sclerotized thread with no muscle fibres. It is likely that all these muscles (122, 123 and 124) serve to alter the capacity of the thoracic cavity by their contraction—the sixth pair of longitudinal muscle (123), by its contraction, may increase the capacity by bulging out the posterior metabasisternum, and the sterno-pleural muscle may reduce it by drawing the pleural and sternal walls closer together, as suggested in mesothorax (p. 59).

These three muscles correspond, both in origin and insertion, to similar muscles of *Dissosteira carolina* (Snodgrass, 1929) and *Dociostaurus maroccanus* (Jannone, 1940).

3. Musculature of the Metathoracic Legs (Figs. 3 A-B, 7 A-C, 9 and 10 A-B)

(a) MUSCLES OF BASIPODITE

These comprise 10 muscles, as in the mesothoracic basipodite. The metathoracic basipodite has 3 posterior rotator muscles while the mesothoracic basipodite has only one; still the total number of muscles here does not increase, for, there are present here only one adductor and 2 abductor muscles, whereas the mesothoracic basipodite has 2 adductor and 3 abductor muscles. The muscles of the metathoracic basipodite are as follows:—

(i) *The tergal promotor of metacoxa* (125) is a long and slender (length 12.15 mm.; breadth 1.71 mm.) muscle which arises from the outer border of the

scutum and at the base of the notal wing-process. It runs downward and slightly backward behind the tergosternal muscle (116) and in front of the depressor bundle of the trochanter (137) and is inserted on the disc of its tendon-like apodeme.

This muscle pulls the leg forward.

(ii) *The first tergal remotor muscle* (126) is long and stout (length 9.90 mm.; breadth 1.80 mm.). It also arises from the scutum, in front of the lateral scutal lobe of its side (*l.scl.*) just externally to and behind the place of origin of the depressor muscle of trochanter, runs downward and backward to its insertion on its own apodeme internally to the second posterior rotator (130) and behind the third rotator muscle (131).

(iii) *The second tergal remotor of metacoxa* (127) is a stout muscle (length 8.55 mm.; breadth 1.62 mm.), but is shorter than the first tergal remotor (126). It arises from the lateral division of scutellum (*l.scl.*), runs downward and backward externally to the first tergal remotor muscle and internally and behind the depressor extensor muscle of the wing (120), and is inserted on its own tendon at the outer posterior angle of the coxal base.

(iv) *The anterior rotator of metacoxa* (128) consists of 2 muscle bundles—a thin bundle (128 i; length 4.5 mm.; breadth 0.9 mm.) and a stout and wedge-shaped bundle (128 ii; length 5.40 mm.; breadth 2.25 mm.). The thinner bundle arises from the crescentic ridge of the posterior metabasisternum (Figs. 3 A-B), and the stout one arises from the outer margin of the metafurcasternum. Both these bundles run together outward and forward to their insertion on the apodeme in the antero-ventral corner of coxal base.

(v) *The first posterior rotator of metacoxa* (Fig. 3 B; muscle 129) is a small, wedge-shaped muscle which arises from the upper posterior margin of the furcasternal apophysis and runs outward and backward to its insertion on a process on the postero-dorsal metacoxal basicosta.

(vi) *The second posterior rotator of metacoxa* (Fig. 3 B; muscle 130) is a large wedge-shaped muscle (length 5.40 mm.; breadth 1.53 mm.) consisting of 2 bundles—a small outer one and a large inner one. Both these bundles arise from the posterior face of sternal apophysis internally to the first posterior rotator muscle, and are inserted on its own apodeme externally to the place of insertion of the first tergal remotor muscle (126).

(vii) *The third posterior rotator muscle* (Fig. 3 B; muscle 131) is longer and slender (5.4 mm.; breadth 0.9 mm.) than the first (129) but shorter than the second (130). It arises from the base of the furcasternal apophysis and runs outward to its insertion on a small process at the postero-ventral corner of the basicosta.

(viii) *The adductor of metacoxa* (132) is a short and stout slip of muscle (length 3.33 mm.; width 1.98 mm.) which arises from the outer part of the

posterior face of the metafurcasternal apophysis below the place of origin of the first, second and third posterior rotator muscles (129-131). It runs downward and backward to its insertion on the posterior part of the ventral basicosta.

(ix) *The first abductor of metacoxa* (133) is a fan-shaped muscle which is much larger (length 9.00 mm.; breadth 3.78 mm.) than the corresponding muscle of the mesocoxa. It arises anteriorly from the metapleural ridge, at the inner surface of the metepisternum and the anterior face of the pleural ridge and is inserted on its own tendon-like apodeme. A small bundle of the muscle is also inserted directly on the basicosta.

(x) *The second abductor of metacoxa* (134) is a short wedge-shaped muscle (length 3.60 mm.; breadth 1.35 mm.) which arises from the metepisternal ridge and the inner surface of metepisternum, externally to the tergosternal (116), tergal promotor (125) and rotator muscle of the wing (119) and is inserted on its own apodeme.

The above muscles (125-134) correspond, both in origin and insertion, to similar muscles of *Dissosteira carolina* (Snodgrass, 1929).

(b) MUSCLES OF THE TELOPODITE

There are 8 muscles of the telopodite, which are as follows:—

(i) *The anterior levator of trochanter* (135 i-ii) consists of 2 bundles of unequal length. These are as follows:—

(a) *The shorter bundle* (135 i; length 3.87 mm.; breadth 0.9 mm.) arises from the ventral part of the inner surface of the coxa and runs outward beneath the posterior levator muscle (136), to be inserted on the anterior of the two long levator apodemes.

(b) *The longer bundle* (135 ii; length 4.50 mm.; breadth 1.44 mm.) consists of 2 groups of muscle fibres which arise together on the distal face of the episternal basicosta and run outward beneath the posterior levator muscle (136) to be inserted on the posterior of the two levator apodemes (Fig. 7 A; muscle 135 ii, *ap.*).

(ii) *The posterior levator of trochanter* (136) is a short, stout muscle (length 4.05 mm.; breadth 1.08 mm.) which arises from the distal face of postero-dorsal basicosta, close to the coxo-pleural articulation and runs outward and slightly posteriorward above the anterior levator muscle (135 i-ii). It is inserted dorsally on the trochanteral corium close to its (trochanter's) posterior articular process (Fig. 7 A, *pox.p.*).

(iii) *The depressor of trochanter* (137 i-iv) consists of 4 bundles of muscle-fibres as follows:—

(a) *The first scutal bundle* (137 i) is slender and long (length 11.25 mm.; breadth 0.45 mm.); it arises from the scutum outside the large median triangular patch and between the places of attachment of the tergal promotor (125) and the first tergal remotor (126). It runs downward and slightly backward closely

behind the tergal promotor muscle (125) and joins with the second scutal bundle (137 ii).

(b) *The second scutal bundle* (137 ii) is shorter (length 10.98 mm.; breadth 0.36 mm.) than the previous muscle. It arises ventrally from the margin of the notal wing-process (*n.w.*) and as it runs downward, it remains closely applied against the outer flank of the tergal promotor muscle (125) and lies in front of the first tergal remotor muscle (126) but externally to the rotator of the wing (119 i-ii). Both the scutal bundles (137 i-ii) join together above the level of the pleural arm, loop round the lower edge of the metapleural apophysis and continue into the coxal cavity, to be inserted on the depressor apodeme on the ventral triangular process (*t.p.*) of the trochanter.

(c) *The sternal bundle* (137 iii) is long and stout (length 3.15 mm.; breadth 1.26 mm.) and arises from the outer posterior part of the sternal apophysis; it runs just behind the second scutal bundle (137 ii) and is inserted on the depressor apodeme of trochanter.

(d) *The coxal bundle* (137 iv) is short and stout (length 2.70 mm.; breadth 0.99 mm.); it arises from the distal face of antero-ventral basicosta of the coxa and runs outward to be inserted on its depressor apodeme.

A slender, tendon-like thread arises from the anterior surface of the metafemur near its distal end where it is flattened and has nerve connections; it runs outward closely against the femur and is inserted preaxially on the median piece of the sagittate process (Fig. 7 B; *Sg.tb.*) of metatibia. Unlike similar threads of the pro- and meso-thoracic femora, this thread is very much shorter, does not extend the whole length of the femur, but, like them, has nerve connections at its proximal end and does not show muscle fibres. It, therefore, appears to be a femoral *chordotonal organ* (Slifer, 1935) rather than the anterior levator muscle of *Dissosteira carolina* (Snodgrass, 1929) and *Dociostaurus maroccanus* (Jannone, 1940).

(iv) *The levator of metatibia* (139 i-iv) consists of 4 bundles of muscle fibres as follows:—

(a) *The anterior-posterior bundle* is the largest of the 4 bundles and arises in a pinnate manner, bundle after bundle, from the anterior and posterior walls of the metafemur between the obliquely disposed 'fish-bones'.

(b) *The dorsal bundle* is large and arises dorsally within the metafemur between the postero-dorsal and antero-dorsal ridges.

Both these bundles are inserted on the large tape-like levator apodeme.

(c and d) *The distal bundles* are short and slender (length 3.60 mm.; breadth 0.36 mm.) which arise near the outer end of the metafemur from the antero-dorsal and postero-dorsal ridges and are inserted one on either side of the distal end of the levator apodeme.

(v) *The depressor of metatibia* (140) is a very long and stout muscle (length 24.30 mm.; breadth 2.25 mm.) consisting of pinnate bundles which arise between the antero-ventral and postero-ventral grooves of the metafemur and converge, bundle after bundle, on its apodeme.

(vi) *The levator of metatarsus* (Fig. 7 C; muscle 141) is a feebly developed muscle as compared to its pro- and meso-tarsal counterpart and consists of a short, thin and pinnate slip of fibres (length 3.60 mm.; width 0.9 mm.) which arise dorsally from the posterior part of the metatibia and are inserted by means of its tendon on the dorsal tibio-tarsal corium.

(vii) *The depressor of metatarsus* (142) is also feebly developed and consists of a thin, pinnate but longer slip of fibres (length 5.40 mm.; breadth 1.35 mm.) which arise fan-wise ventrally from the distal part of metatibia and are inserted on the ventral tibio-tarsal corium.

(viii) *The depressor of metapretarsus* (143 i-iii) consists of 3 bundles of which only the femoral bundle is well developed while the other 2 tibial bundles are vestigial. These 3 bundles are as follows:—

(a) *The femoral bundle* (143 i) is a small slip of fan-shaped muscle (length 10.8 mm.; width 2.25 mm.) which arises in a broad furrow in the anterior part of metafemur between the antero-ventral and the postero-ventral grooves and is inserted on its very long apodeme.

(b and c) *The first and second tibial bundles* (143 ii, iii) are very feebly developed (each: length 3.60 mm.; breadth 0.27 mm.) and arise respectively from the anterior ventral and the posterior ventral parts of the metatibia where each of them is closely applied to the tibial wall. After running a short distance, they are inserted on the common long apodeme.

These muscles (135 i-ii to 143 i-iii) correspond, both in origin and insertion, to similar muscles of *Dissosteira carolina* (Snodgrass, 1929). The anterior levator muscle of the trochanter (135 i, ii) has, however, 2 bundles in *S. gregaria*, and only one in *D. carolina*. The chordotonal organ of the metafemur corresponds to what Snodgrass (1929) has called the anterior levator muscle of the metatibia of *D. carolina*. But since this structure does not show any muscle-fibres and has nerves running into it, it resembles the chordotonal organ of *Melanoplus differentialis* (Slifer, 1935).

V. SUMMARY

1. A critical and complete account is given of the external morphology of the notal, pleural and the sternal structures of the pterothorax (meso- and metathorax) of the Desert Locust, *Schistocerca gregaria* (Forskål), phase *gregaria*.

2. A comparative study of the pro-, meso- and meta-coxae is made in order to explain the progressive structural complexity from pro- to meta-coxae.

3. An account of the epipleurites, axillary and accessory sclerites of the tegmina and the wings and their venation is given.

4. There are 59 muscles in the pterothorax. Of these, 31 muscles (Nos. 85-115) belong to the mesothorax and 28 muscles (Nos. 116-143) to the metathorax. In the mesothorax 10 muscles move the tegmen: 6 muscles (Nos. 85-90) produce the up and down strokes, 2 muscles (Nos. 91 and 92) twist or partially rotate the tegmen, while 2 muscles (Nos. 93 i-ii and 94) flex and extend it. There are 3 muscles (Nos. 95-97) in relation to the movement of the mesothorax; of these,

the sterno-pleural muscle (No. 97), by its contraction, alters the capacity of the mesothoracic cavity by bringing the pleural and sternal walls closer together and may be concerned in the respiration of the locust. There are 25 muscles which move the mesothoracic legs, thus: 11 muscles (Nos. 98 i-ii to 107) belong to the mesocoxa and move the leg as a whole, and 14 muscles (Nos. 108 i-ii to 115 i-iii) move the various segments of the leg. The cuticularized thread-like structure (No. 111) in the mesothoracic femur, so far as is evident from dissections and whole mounts, appears to be a chordotonal organ rather than a muscle, for it does not show any muscle fibres and has a nerve running into it. Of the above-mentioned mesothoracic muscles, the second oblique dorsal muscle of the tegmen (No. 88) and the tergò-pleural muscle (No. 90) are peculiar to *Schistocerca gregaria*, while each of the depressor extensor muscles of the tegmen (No. 93 ii), the tergal promotor of the mesocoxa (98 ii) and the levator of the trochanter (No. 108 ii) has an additional second bundle.

5. Of the 28 muscles of the metathorax, only 8 move the wing, thus: 2 muscles (Nos. 116 and 117) produce the up and down strokes, 2 muscles (Nos. 118 and 119 i-ii) twist or partially rotate the wing and 2 muscles (Nos. 120 and 121 i-ii) flex or extend it. There are 3 muscles (Nos. 122-124) in relation to the movements of the metathorax, but there being little scope of movement between the meso- and meta-thorax, the 5th and 6th pairs of longitudinal muscles (Nos. 122 and 123) are greatly reduced—the 5th pair having been reduced to a defunct sclerotized fibre without any muscle element in it. The 6th longitudinal pair (No. 123) and the sterno-pleural muscle (No. 124) serve to alter the capacity of the metathoracic cavity and may be helpful in respiration of the locust. 19 muscles belong to the metathoracic leg; of these, 10 belong to the basipodite (coxa) and move the leg as a whole, while 8 muscles (Nos. 135 i-ii to 143 iii) move the various segments of the leg. One of these latter, viz., No. 138, represents the chordotonal organ (found to be present in this location in *Melanoplus differentialis* by Slifer, 1935) rather than a muscle; and the anterior levator of metathoracic trochanter has an additional second bundle.

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THE BIOLOGY AND CONTROL OF THE WHEAT BUG, *EURYGASTER MAURA* LINN., IN BALUCHISTAN

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INTRODUCTION

The wheat bug, *Eurygaster maura* Linn. (Pentatomidae), locally known as 'kakhai', 'juju' or 'jeeru', is fairly common in the north-eastern parts of Baluchistan and during recent years the extent of damage by this bug to wheat crop has increased so enormously that it has now become a pest of first-rate importance. A brief account of this insect was given by Pruthi (1943). In view of the seriousness of the pest, detailed studies on the biology and control measures were made by the writers during the years 1940-1943 and the results are presented in this paper.

The writers feel indebted to Dr. H. S. Pruthi, formerly Imperial Entomologist, New Delhi, for his valuable criticism and useful suggestions in the preparation of this paper and to the Imperial Entomologist, Imperial Agricultural Research Institute, New Delhi, for the identification of the species.

DISTRIBUTION

Eurygaster maura Linn. is widely distributed in almost the whole of the European Continent, North Africa, Caucasus, Siberia, Japan, China, East Indies, etc. (Oshanin, 1904). *Eurygaster maura* and the allied species, *E. intigriceps* Put., *E. hottentota* F. and *E. austriaca* Schr., are known to be serious pests of wheat and other cereal crops in the Middle East—Syria, Iraq, Iran, Transcaspia, etc., and in Central Europe and Southern Russia (Sorauer, 1932). Serious damage to wheat crop as a result of outbreak of *Eurygaster maura* was reported from the province of Verona in Italy (Malenothi, 1933); from Hungary in 1931 (Manninger and Manninger Jr., 1934) and from northern Caucasus (Arkhangenskii, 1941). A species of *Eurygaster* is also one of the most serious pests of wheat crop in Iran where it is known as 'sin'. The senior author during his visits to Iran in 1942 and 1943 in connection with locust work, saw certain campaigns organized by the Plant Protection Officer of Iran against this pest in southern and south-western parts of Iran. According to Pruthi (*op. cit.*) it is probable that *Eurygaster* also occurs in Afghanistan.

In India, the first report of *Eurygaster maura* doing damage to wheat was received by the Imperial Entomologist, New Delhi, in April 1926 from Kulu,

though the Imperial Pusa collection also contains specimens collected from Kulu in 1919 and 1920 (Pruthi, 1943).

In Baluchistan, the pest was first reported in the Upper Zhob Valley (Zhob district) in 1937 and during recent years it has also been observed doing very serious damage to wheat crops in Kohlu tehsil (Sibi district) and Barkhan Sub-division (Loralai district).

On account of the proximity of North-West Frontier Province to Zhob district and the fact that the climate is somewhat similar to that of Baluchistan and the Middle East Countries, Pruthi (*op. cit.*) suspected that the pest may also occur in the North-West Frontier Province.

FOOD PLANTS AND NATURE AND EXTENT OF DAMAGE

In Baluchistan, this bug is a serious pest of wheat. It has also been observed attacking maize, oats and barley but the damage caused to these crops is not so severe.

In the north-eastern parts of Baluchistan, wheat is sown by about the middle of October and continues up to the middle of January. Early in February the bugs, which spend the winter in the hills, fly in swarms to the valleys where wheat is sown. They actively suck the juice of wheat plants which as a result thereof, become stunted in growth and eventually wilt. Early in spring, the females lay their eggs on the undersides of the leaves and the newly hatched nymphs first settle on the upper part of the young shoots and suck the sap. Later on the infestation spreads to the ears where the grains, which are in "milky stage", are attacked causing them to turn white. Usually 1-12 adults can be seen attacking one ear head. The infestation spreads from one field to another and continues up to the harvest by which time the bugs are also fully grown. As a result of feeding by the bugs, apart from the effect of dessaping, the affected shoots and the young ears are killed resulting in the arrest of the formation of seed. The quality of gluten in the affected grain is greatly depreciated and the resultant flour from it becomes unsuitable for baking purposes. It has been estimated that 50-70 per cent. of the wheat crop is spoiled in Zhob district due to the attack of this bug while the percentage of infestation in Kohlu tehsil and Barkhan Subdivision is 50-90 and 30-40 respectively.

After the wheat crop is harvested, *i.e.*, from the end of May to middle of June, the adults fly back to the adjoining hills where they pass the summer and winter season. Mr. C. K. Samuel, Assistant to the Imperial Entomologist, surveyed the food plants of this pest and reported (report not published) that during summer they feed on the following weeds in the hills:—

1. *Peganum harmala* (Family Rutaceae)—'Harmal'.
2. *Alhagi camelorum* (Family Leguminosae)—Camel Thorn.
3. *Haloxylon griffithi* (Family Chenopodiaceae)—'Shorae'.
4. *Salsola foetida* (Family Chenopodiaceae)—'Sajji'.

5. *Suaeda fruticosa* (Family Chenopodiaceae)—‘Askhar’.

6. *Tamarix gallica* (Family Tamaricaceae)—‘Ghaz’.

During winter they are found hiding under stones and on the above mentioned weeds, etc.

DESCRIPTION OF VARIOUS STAGES IN LIFE-HISTORY

The Egg.—The eggs are laid on the undersides of leaves generally on the lower part of the young wheat plants in longitudinal rows which are more near the midrib. They are firmly attached to the surface by a sticky substance. The egg is round and shining green and 1 mm. in diameter. The surface is covered with extremely fine punctations irregular in placings. After two to three days the colour of the egg changes from shining green to black and becomes deeper as the nymph develops inside. A day or two before hatching the young nymph can be seen moving its head in the egg-shell and emergence takes place through a broad fissure; embryonic membranes remain attached to the armature as a fan-shaped appendage.

The Nymph.—Almost immediately after hatching, the tiny nymph moves about and ultimately settles down at the base of the earhead where it starts feeding by sucking the sap through its tiny stylet. The number of instars and moulting activities of the nymphs have been studied in detail. Five instars have been noted in Baluchistan and the description of the various instars is as follows:

First instar.—Average length 1.5 mm., maximum width 0.8 mm. Body convex dorsally and abdomen biconcave ventrally. Abdomen dorsally brown, except first segment, which is dark brown. On venter, abdomen is light brown becoming dark brown towards the margins. Sides of abdomen black on both surfaces. Dorsal surface of abdomen marked with five black transverse stripes; anterior one narrow, second wide, third widest, while the fourth and fifth are very small and in some cases merely dots. Head and thorax black, except median region of thorax ventrally which is light brown. Eyes deep red, prominent at the base angles of the head; facets few and large. Legs long, brown in colour. The tibiae and tarsi with short light brown hairs. Antennae brown to almost black except bases of ultimate and penultimate joints which are yellow in most cases. Rostrum short and stout reaching to third abdominal segment, pale brown in colour.

Second instar.—Average length 3.5 mm.; breadth 2.2 mm. General shape and colouration as in first instar, but ventral surface of head and abdomen becoming dark brown. Coxae and trochanters light brown. Antennae dark brown, except the extreme bases of penultimate and basal half to one-third of ultimate joints which are yellow. Femora sparsely and tibiae and tarsi hirsute. The transverse lines on abdomen are as in first instar, except that the second and third are broader and the fifth smaller than in that instar.

Third instar.—Average length 5.3 mm.; breadth 3.4 mm. In this instar there is a great variation in the colouration of different individuals. Though usually the insects are assignable to a light or dark variety, there are often intermediate forms.

In both varieties the venter is brown except at the margins which are black. The ground colour of the dorsum is also brown. The five black transverse lines are still represented. The anterior three are more pronounced than in the preceding instars, while the posterior two are less conspicuous or even absent. The second and third are now much wider than formerly, and are really a series of spots and blotches rather than a simple line as

previously. Antennae dark brown to black, except the base of the ultimate joint which is yellow. Thoracic margins are now flattened to form a narrow flange which varies from brown to black. In the median region of the head are two parallel lines which are deep brown to black and run the length of the head, transversing grooves from the base of the probocis for about two-thirds their length. In the darkest individuals these lines are not distinguishable as such.

The colouration of the remaining parts in light specimens is as follows:—Head and thorax brown, lightly mottled with black; the black being confined to irregularly placed punctations. Yellow portion of the antennae very conspicuous. Coxae, trochanters and femora light brown; tibiae and tarsi brown.

Dark specimens differ in that the mottling of the head and thorax is much more pronounced and in certain cases the whole head and thorax is uniformly black and shining. On the abdomen the dark portions are again more pronounced.

Fourth instar.—Average length 7.4 mm.; breadth 4.3 mm. Dorsum dark brown. Head and thorax mottled with black; abdomen less thickly so. The degree of mottling varies, some individuals appearing uniformly brown, while in others the head and thorax appear quite black. On the abdomen the dots are arranged more or less in transverse lines, elsewhere the placing is less regular. The black is practically confined to punctations. The thorax is mottled more heavily towards the margins. There is a black spot on each side of the mesothorax one-third away from the median line towards the anterior and usually another spot on the posterior edge of the metathorax. The longitudinal lines of the head conspicuous. Antennae with basal joint yellow suffused with brown, remainder brown. The lateral margins are brown to black, narrow on head, wider on thorax, and very variable on abdomen. Here it may be merely a line on the margin widening to a spot at the posterior angle or it may be widened out at both angles or evenly wide over the whole length. Other abdominal markings are also variable. At least there are four black spots, more often six, forming a square or rectangle. The posterior four mark the position of glandular opening from which a secretion is emitted. The area about these glands is somewhat elevated. In darker specimens these areas are so thickly mottled as to appear quite black. Venter lighter in colour than dorsum, the lateral edges brown to black. The lateral band varies as in dorsum. Probocis light brown with tip black and reaching almost to tip of abdomen. Stylet brown, held partly exerted. Tibiae, tarsi and remainder of legs brown. Femora sparsely and tibiae and tarsi rather thickly hispid.

Fifth instar.—Average length 8.3 mm.; breadth 5.4 mm. Dorsum dark brown with black dots, the black again confined to depressions which are larger on the thorax than on the head and abdomen. The punctations at times confluent and on abdomen are arranged more or less in lines. The entire lateral margins of the sclerites black; this black portion widening out, at least at the angles, but sometimes uniformly wide for whole length of abdomen. Eyes dark brown; ocelli marked by red spots. Probocis light brown with tip black; stylet brown. Head with black dots on posterior margin close to median. Antennae brownish black to black, except the basal half of ultimate and penultimate joints which are light brown. Prothorax with the flange black, sometimes with a light brown stripe towards the margin. Scutellum with five black spots, four on the anterior margin and one on the apex. This last spot sometimes absent. In addition, on the scutellum there is often a faint black transverse line on each side near the anterior margin. Wing pads well developed; generally thickly mottled with black towards the tips. Pronotum somewhat expanded sideways; but not wider than the greatest width of the abdomen. The three raised areas about glands conspicuous with black lines, or in lighter specimens black lines represented by about six spots. Venter lighter dark brown than dorsum. Abdomen usually with very fine brown spots. Legs brown becoming darker towards the tarsi which are shining brown to black. Femora, tibiae and tarsi hispid; in darker individuals the tibiae may be dark brown also,

The Adult.—The adults are sun loving insects and during day time they are seen on the ears in large numbers while at night they take shelters under weeds, etc., and in the cracks of the soil. When touched they have the habit of feigning death and if kept for some time on the hand, itching sensation is caused on the skin. When flying they produce hissing noise.

Distant (1902) describes the adult as follows:—

“Ochraceous, more or less suffused with dark or purple-brown and thickly and darkly punctate; connexivum with large quadrate dark spots formed by dark punctures.

This species vary in colour from almost uniform ochraceous to luteous with fasciae and suffusions of various shades of brown, in some varieties nearly almost suffused with dark brown. Scopoli (*Ent. Carn.*, p. 120) states that in all the varieties the colour of the under-surface is always the same but this cannot be maintained.”

DURATION OF VARIOUS STAGES AND SEASONAL HISTORY

The seasonal history of *Eurygaster maura* Linn. has been studied in almost all the countries where it occurs and is practically the same at all places, the duration of the various stages being of course different in different localities. As a result of investigations carried out by us during the years 1940–1943 it has been ascertained that as in other countries, there is only one generation of the bug in a year in Baluchistan.

Observations during the four years 1940–43 show that oviposition commenced between February 20 and 27 and ended between March 22 and 30. The incubation period of the eggs varied from 7 to 15 days with an average of 10.7 days. Hatching commenced between February 28 and March 10 and ended between March 31 and April 6.

The nymphs on hatching move about and ultimately settle down either on the tender stem or at the base of the earheads where they start feeding by sucking the sap through their tiny stylets. As they grow, moulting takes place until five instars are completed to reach the adult stage. The duration of the various instars based on 25 individuals is given in Table I.

TABLE I. *Duration of instars*

Instar	Duration of instars in days		
	Maximum	Minimum	Average
I	8	5	
II	10	7	
III	11	8	
IV	15	27	21.1
V	20		

It is during the nymphal stages that feeding period of the nymphs re

1940 1941 1942 1943

37.4 days. It has been observed that the nymphs from third to fifth instars after finishing with one field crawl to the adjoining ones.

In 1940, the first adults were seen on April 29 and the last on May 12. The dates of first emergence of adults during the three subsequent years were April 30, May 2 and April 25 and emergence continued upto May 10, May 15 and May 8 respectively. The adults soon after emergence also suck the sap from the earheads and as many as 1-12 adults have been counted on some earheads. As soon as the wheat crop is harvested (end of May to middle of June), the adults are seen flying in swarms and going to the adjoining hills where they pass the summer and winter season. They do not go beyond a height of ten thousand feet on the hills out invariably remain just above the foot of the mountain ranges.

Early in February, when the wheat plants are quite young (about a foot and a half in height), the adult bugs which pass the winter in the hills, are seen flying in swarms to the wheat fields. They settle on the young plants and start sucking the juices.

After about a fortnight, copulation takes place and lasts from $\frac{1}{2}$ hour to 2 hours. Invariably it takes place at night but copulating pairs have also been seen during daytime. The preoviposition period varied from 2 to 5 days with an average of 3.2 days. The average time of egg deposition was 7.2 days, varying from 5 to 9 days. Table II gives the oviposition records for the year 1941.

TABLE II. *Oviposition records of Eurygaster maura for 1941*

Observation No.	No. of adults	Date of				Number of days	
		Copulation	First oviposition	Last oviposition		Before oviposition	Of oviposition
1	2	Feb. 17	Feb. 20	Feb. 26		3	9
2	9	" 20	" 24	Mar. 1		4	9
3	5	" 25	" 27	" 3		2	6
4	8	" 28	Mar. 3	" 6		3	6
5	4	Mar. 2	" 6	" 10		4	8
6	7	" 6	" 9	" 12		3	6
7	6	" 7	" 10	" 13		3	7
8	3	" 11	" 16	" 19		5	8
Average						3.3	7.3

The egg laying activities of the female were observed in detail. The female the margin. Scutellum apex. This last spot sometimes over the undersurface of the leaf and selects a place black transverse line on each raises its ovipositor and places it on the leaf surface. generally thickly mottled with black spots, exposing the upper surface beneath the out- ways; but not wider than the greatest stands firm, forelegs upright, mid and hind glands conspicuous with black lines, or in position of the egg is a momentary operation six spots. Venter lighter dark brown than do placed near the egg already laid and spots. Legs brown becoming darker towards the femora, tibiae and tarsi hispid; in darker individuals eggs are laid in longitudinal rows.

TABLE III. *Life-history data of Eurygaster maura* Linn. (1940-1943)

Year	First eggs deposited on	Oviposition ended on	Incubation (days) Range-Average	Hatching of eggs		Feeding period of nymphs (days) Range-Average	Emergence of adults		Life of adult (days) Range-Average	Life cycle (days) Range-Average
				Commence-ment	End		Commence-ment	End		
1940	23. II	26. III	7-13	8. III	3. IV	28-40	29. IV	12. V	279-290	314-343
1941	20. II	22. III	8-13	28. II	31. III	25-38	30. IV	10. V	260-282	293-323
1942	27. II	30. III	7-15	10. III	7. IV	26-43	2. V	15. V	272-298	305-356
1943	21. II	29. III	9-14	2. III	6. IV	27-41	25. IV	8. V	278-302	210-360

The number of eggs deposited by a single female at a time was 12-15 and 10-12 batches in longitudinal rows are laid in all. The average number of eggs deposited by a single female was 139.3—ten females depositing 1,393 eggs. The maximum number of eggs deposited by a single female was 180.

The length of the life of the adult varied from 260 to 302 days, the average being 283.9 days.

The life-history data are summarized in Table III.

PARASITES AND PREDATORS

Important natural enemies of this bug are known in other countries and these include Scelionid egg-parasites of the genus *Telenomus* which are considered to be very efficient in as much as they can parasitise up to 96 per cent. of the host eggs, two genera of Tachinids, viz., *Phasia* and *Clytiomyia* and an Asilid (Dobrovolski, 1913; Malenotti, 1933; Tischler, 1938). It is also interesting to note that Chappellier (1923) found a large number of nymphs of this bug in the body of the nestlings of the common rook.

In Baluchistan no parasite of the bug has so far been observed. An Asilid has, however, been found preying on the nymphs. The Indian house-sparrow, *Passer domesticus indicus*, which appears in very large numbers in wheat fields also destroys both the adults and nymphs.

CONTROL METHODS ADOPTED IN BALUCHISTAN

Pruthi (*op. cit.*) has given a brief account of the control methods which are in vogue in other countries. In Baluchistan only two methods, viz., (i) hand picking of the bug and (ii) burning the weeds, etc., in the hills which harbour the pest during winter, were employed. The following are the details of the work done during the years 1940-43:—

(i) *Hand picking of the bug.*—In Baluchistan, there is scarcity of labour and it was not possible to get the adults hand picked at out-of-the-way places by daily paid labour. After trying for a week, the most effective and cheapest method discovered was the purchase of bugs. This had the additional advantage of creating an interest amongst the people. Accordingly, it was announced that one seer of the bug would be purchased for a rupee. By about the middle of February, when the bugs had migrated from their winter headquarters and settled on wheat crop, hand picking was started. Every effort was made to get them collected before mating and egg-laying. Earthen receptacles or empty kerosene oil tins containing some water and a thin layer of kerosene oil over it were given to the collectors who by shaking the earthenware dislodged the bugs into these receptacles. As the bugs cause itching sensation on the skin, the collectors had to tie old cloth on their hands when collecting the bugs.

The operations continued each year from the middle of February to the end of May and it has been estimated that one collector can bring 1½ seers of these bugs during the working hours of a day. Table IV gives the approximate area

TABLE IV. Statement showing the approximate area cleared and amount of bugs destroyed in various tehsils (1940-1943)

Locality	1940				1941				1942				1943			
	Approx. area cleared (acres)	Wt. of adults purchased			Approx. area cleared (acres)	Wt. of adults purchased			Approx. area cleared (acres)	Wt. of adults purchased			Approx. area cleared (acres)	Wt. of adults purchased		
		Mds.	Srs.	Cht.		Mds.	Srs.	Cht.		Mds.	Srs.	Cht.		Mds.	Srs.	Cht.
Fort Sandeman tehsil	95	23	8	4	126	30	15	7	80	19	27	8	120	29	21	8
Kohlu tehsil	210	50	10	6	195	48	23	6	220	54	8	6	258	63	29	4
Barkhan Subdivision	65	15	24	8	70	17	11	4	90	22	6	4	75	18	27	8
Total	370	89	3	2	391	96	10	1	390	96	2	2	453	111	38	9

Note.—It has been estimated that about 500 bugs weigh one chatak.

cleared and the total amount of bugs destroyed in various tehsils every year. In Fort Sandeman and Kohlu tehsils and Barkhan Subdivision, the average yield of wheat per acre is ten maunds. In those fields where hand picking of the adults was carried out, the average yield was eight maunds while where no control was adopted it was hardly three maunds per acre. The average cost of control per acre was eight to ten rupees depending upon the degree of infestation. By incurring this expenditure there was a saving of five maunds per acre which at a normal rate of rupees seven per maund during these years brought an additional income of approximately Rs. 35 per acre.

(ii) *Burning weeds in the hills.*—When the wheat crop is harvested, the bugs fly back to the neighbouring hills and suck the sap of the weeds as already mentioned. During winter they live under these weeds and as many as 70–83 have been counted on one weed plant. Burning of these weeds was undertaken from November to January every year. In some cases flame thrower was also used but the usual method employed was by putting a heap of dried weeds over the plant containing bugs and setting fire to the heap. Table V gives the details of this work done in each tehsil.

TABLE V. *Statement showing the number of bushes burnt (1940–1943)*

Locality	Approximate number of bushes burnt				
	1940	1941	1942	1943	Total
Fort Sandeman tehsil ..	15,678	16,439	15,334	17,455	64,906
Kohlu tehsil ..	70,835	75,753	69,536	73,676	289,800
Barkhan Subdivision ..	45,661	50,341	48,771	51,789	196,562
Total ..	132,174	141,533	133,641	142,920	551,268

Note.—It has been estimated that one labourer can burn about 100–150 bushes per day.

By adopting these control measures the further spread of the pest has been checked to a very great extent. Efforts are also being made to find out cheaper and more efficient methods of control.

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THE BIOLOGY OF SHOT-HOLE BORER (*SCOLYTUS AMYGDALI* GUER.) IN BALUCHISTAN

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I. INTRODUCTION

The Shot-hole Borer, *Scolytus amygdali* Guer. (Scolytidae: Coleoptera) is fairly common in Baluchistan and in recent years damage by it to fruit trees has increased so enormously that it has now become a pest of first rate importance. A brief account of this insect was given by Janjua and Samuel (1941), but in view of its importance, the writer has made a detailed study of the biology of the insect during the last few years and the results are presented in this paper.

The writer feels indebted to Dr. Khan A. Rahman, Government Entomologist, Punjab, for his valuable criticism and to the Imperial Institute of Entomology, London, for the identification of the species.

II. DISTRIBUTION

The family Scolytidae is pretty widely distributed throughout the world and at least 2,000 named species of this family are so far known. Of these, more than 300 species occur in India, the majority of which occur on forest trees. *Scolytus amygdali* Guer. has been recorded as a pest of almond trees in Spain and Palestine (Priego, 1915; Blair, 1920); of plums and almonds in Cyprus (Wilkinson, 1925; Morris, 1930); and of peaches and plums in Bulgaria (Chorbadzhiev, 1930). In India, it was first recorded by Janjua and Samuel (1941) from Baluchistan where it is found throughout the fruit-growing tracts of the districts of Quetta-Pishin, Zhob and Loralai. An allied species, *Scolytus rugulosus* Rat., is the well-known pest of fruit and shade trees in the United States of America. Another species, found doing damage to fruit trees in Baluchistan, is *Scolytus fasciatus* Rtt. but it is so far not a serious pest.

III. FOOD PLANTS AND NATURE AND EXTENT OF DAMAGE

This beetle is one of the most serious pests of apricot, almond, cherry, peach, nectarine, apple, plum and quince trees in Baluchistan. Trees of all sizes are attacked and once a centre of infestation has started, the insect by means of successive generations, spreads out attacking the trees in the whole of the garden. If neglected, most of the trees in an orchard are killed in a few years. The damage done by the insect can well be estimated by the fact that in an apricot limb six feet long and about three inches in diameter, got from a garden at Quetta, as many as 10,256 'shot-holes' made by the beetles were counted. Four months earlier, this limb had only a negligible attack of the insect.

The damage caused by the shot-hole borer is due to the feeding of both adults and larvae. The adults cause twig and limb injury to the trees. In twig

injury, the adults bore shot-holes in the new wood at the bases of buds and fruit spurs. A considerable amount of gum exudes from such punctures resulting in the drying up of most of the bud and fruit spurs. Limb injury by the adults is due to their tunnelling through the inner bark and cambium. Entrance holes are cut into limbs and trunks to the bast and sap wood and as a result of their attack, the cell sap oozes out through the holes and solidifies into lumps of resin. It has been noticed that trees, which are heavily infested by the pest, become studded throughout the trunk, limbs and twigs with masses of gum.

The larvae on hatching bore galleries in the bast layer, thus grooving the sap wood. When sufficiently numerous, these larvae reduce the entire inner bark to powder and remove the whole of the bast layer of the tree which ultimately dies.

It has been estimated that thirty to forty per cent. of the cherry trees in the province and ten to fifteen per cent. of apricot and almond trees are infested by the beetle, while the percentage of infestation on other fruit trees varies from five to seven.

IV. DESCRIPTION OF VARIOUS STAGES IN THE LIFE-HISTORY

The Egg.—The eggs are laid in a row along the sides of the egg gallery made by the female in the bast layer where they are embedded in frass. The egg is spherical in shape, shining and creamy white in colour and about 0.55 mm. in diameter. The surface is regular and unsculptured. About 24 hours before the shell breaks open, the egg loses its shining appearance and shrinks slightly.

The Larva.—The newly hatched grub is a minute white dot. During the next 24 hours it commences to feed and excavates a tunnel almost at right angles to the egg-gallery. The curved shape is, however, easily recognizable by the time it has bored about 6 mm. away from the egg-gallery. The larva is legless, wrinkled and curved; it is capable of considerable contraction and expansion assuming different curvatures. The full-grown larva is about 5.8 to 6 mm. in length and 2.1 to 2.5 mm. in breadth and may be described as follows:—

Oblong, cylindrical, thicker anteriorly, feebly shining, finely granulate or rugose, whitish; head above and at the sutures below, and palpi, brownish ferruginous, clypeus paler, mandibles black. Head small, clypeus distinct, feebly emarginate in front, anterior and posterior margins nearly parallel, labrum brownish dusky, semicircular, bearing on the anterior margin three to five punctiform impressions and a few setae; mandibles smooth, rather blunt; palpi biarticulate, the basal joint paler, short and thick, the second brownish, more slender, antennae two-jointed, minute, situated near the base of the mandibles, just above this a puncture which seems to contain a single minute ocellus. Thoracic segments somewhat thicker than the abdomen, more densely granulate and sub-opaque, the cervical shield with the posterior margin deeply notched on each side, a densely granulate and opaque anterior and posterior border and median line, the latter sulcate and narrowed in front, and lateral lines extending forward each side from the notches in the posterior margin, but becoming obsolete before attaining the anterior border, the remaining spaces shining and feebly rugose; following segments finely wrinkled transversely, and granulate. Body posteriorly subtruncate, anal segment quadrate, densely granulate and opaque, the anal aperture in the form of an x. Spiracles faintly darker than ground colour surrounded by concentric wrinkles.

When full fed, the larva changes into a pupa at the end of its gallery which may be slightly enlarged at the extremity, a small depression being eaten out in the bark or sap wood.

The Pupa.—The pupa is soft, about 4 mm. long and 1.5 mm. broad, white or creamy white, and has the general shape of the beetle. The legs, antennae and wings are pressed close to the thorax. The head is not visible from above, being covered by the prothorax. None of the cephalic sutures are discernible except antennae and mouth parts which are well set. The mandibles are distinct and pigmented even in the young pupae, but the maxillary lobes and labium are rather indistinct. The shape and relative proportions of the pronotum are very similar to those of the adult. On the mesothorax there is a large spiracle located in the triangle visible between the prothoracic femur, elytron and pronotum. The mesonotum is subrectangular. The base of the elytron is fused with the tergal area. The prothoracic and mesothoracic legs are plainly visible for the most part, but of the metathoracic legs only a portion of the coxae can be seen. The remainder of these legs is concealed by the elytra. The metathoracic wings are also concealed under the elytra. In the abdomen there are 10 segments, of which the sternites of the first two are not exposed. Due to the ventral curvature of the abdomen, the 9th and 10th segments are not visible in a dorsal view. Segment 9 is very small and is not clearly separated from segment 8 ventrally. Segment 10 is reduced to four minute lobes around the anus. The spiracles lie in the epipleural regions close to the anterior borders of segments 1 to 7. They can best be seen in older pigmented specimens. The one on segment 7 is relatively obscure.

The pupae, finally, change into the adult beetles. They are white at first, but soon turn light yellow and then brown. The beetles remain in the pupal cells for a few days and on maturing crawl out of the chamber and bore their way straight through the bark of the tree.

The Beetle.—The adult beetles are not seen during the day as they come out from the trees at night. The beetle measures 4 to 4.5 mm. in length and 1.5 to 1.75 mm. in breadth and may be re-described as follows:—

Elongate oval, brown, feebly shining, sparsely clothed with whitish hair; antennae, tips of femora, tibiae, tarsi and usually the apical margins of elytra yellowish brown. Head finely and very densely punctate above, front finely longitudinally aciculate, more densely hairy, remainder of head nearly glabrous, beneath strongly transversely striate. Thorax sparsely hairy, disc glabrous; more coarsely punctate, less densely on the disc, the punctures arranged in irregular lines. Abdomen without either tubercle or spine and ending in a weak notch, velvety. Elytra longer than thorax, strongly denticulate like a saw at their extremity, tips serrate, surface striate, striae with close-set punctures, as coarse as those of the thorax.

V. DURATION OF VARIOUS STAGES AND SEASONAL HISTORY

As a result of investigations carried out during 1938–41, it has been ascertained that there are four generations of the insect in a year in the Quetta valley. The studies were started with the first brood eggs deposited during 1938.

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First Generation.—The female on boring a small 'shot-hole' through the bark reaches the bast layer and excavates an egg-gallery in which she deposits her eggs.

Observations during the four years show that oviposition commenced between 18th and 29th April and ended between 19th and 27th May. The incubation period varied from 26–71 hours with an average of 52 hours. Hatching commenced between 21st and 30th April and ended between 20th and 28th May.

The larvae on hatching bore in the bast and sap wood; they excavate their galleries almost at right angles to the egg-gallery and parallel to each other running along the circumference of the attacked limb. The first few millimetres of the larval galleries are usually excavated entirely within the phloem and the larva is not then visible. Very shortly the larvae cut entirely through the inner bark with the result that the sap wood is scored throughout the length of the larval gallery. With the growth of the larvae, the galleries also increase in size and are tightly packed with frass and excrement. As the larval galleries are extended, they diverge forming a characteristic fan-shaped pattern. Occasionally, in heavy infestations the larval galleries may cross and recross or two larvae may follow the same tunnel. The feeding period of the larvae ranged between 25 to 38 days with an average of 29.6 days.

The length of the larval galleries from which adults emerge was found to vary greatly, the longest being 73 mm. and the shortest 12 mm. The average length of 454 galleries was found to be 40.6 mm.

When full fed, the larva eats out a chamber of sufficient size at the end of the gallery, for pupation. The pre-pupation period varied from 4 to 9 days with an average of 6.9 days.

Pupation commenced between 23rd and 30th May and ended between 26th June and 6th July. The pupal period varied from 10 to 15 days with an average of 12.3 days.

During the latter part of the pupal period, the light colour of the pupae slowly darkens. After the adult becomes somewhat hardened, it bores its way straight through the bark of the tree. The emergence holes are round and slightly larger in diameter than the beetle. It then crawls about for a short time before flying away to feed or seek a place to breed. Emergence of adults began between 7th and 13th June and ended between 5th and 14th July. The average adult life was 7.4 days.

The male beetle prepares a special pairing chamber in the bark for copulation with the female. The latter either enters through the hole made by the male or makes her own entrance hole for copulating with its mate. Such a hole may be distinguished by the presence of an exit-hole surrounded by frass.

Copulation lasts from 5 to 8 hours and invariably takes place at night. The pre-oviposition period varied from 2 to 3 days with an average of 2.6 days.

The female now starts constructing the egg-gallery. In the work of excavation, each female is generally accompanied by a male. The female does most of the excavation work with the male usually close behind. The female pushes the bored dust backwards with the mandibles and fore-tibiae, working it past the body with the legs and by rotating the body. The male, in turn, pushes the dust backwards until it is finally ejected from the entrance burrow. Ordinarily great care is taken not to let frass accumulate in the egg-gallery. The egg-gallery is carried in an upward direction parallel to the long axis of the tree and is made mainly in the bast layer but also grooves more or less deeply the sap wood. It is from 5 to 7 cm. in length with an average of 6.2 cm. After completing the egg-gallery, the female forms tiny pocket-like depressions on both sides of the egg-gallery wall. The female then proceeds backwards to the depression, slightly raises the abdomen, and an egg suddenly appears in the space. She immediately gathers some frass and packs the egg in tightly, using the fore-tibiae and mandibles. Only one egg is deposited in each depression. When all the eggs are laid the female goes back to the opening of the burrow and dies there with the posterior end of the body projecting. The body of the female thus blocks the opening and prevents the entrance of parasites or predators which might kill the eggs or young larvae.

The average number of eggs deposited per female beetle of the first brood was 65.4—ten females depositing 654 eggs. The maximum number of eggs deposited by a single female was 68. The life-cycle of the first generation varied from 42 to 60 days with an average of 52.9 days.

Second Generation.—During 1938–41 the first eggs of second brood were deposited between June 9 and 16 and oviposition continued up to July 7 and 16. The incubation period of the eggs varied from 21 to 59 hours with an average of 44 hours. The eggs commenced hatching between June 11 and 18 and continued to hatch up to July 8 and 17. The feeding period of the larvae ranged from 23 to 35 days with an average of 27.3 days. The pre-pupation period varied from 3 to 7 days with an average of 5.2 days. The first pupation took place between July 17 and 26 and the last between August 9 and 17. The pupal period varied from 7 to 12 days with an average of 9.7 days.

During the four years the first beetles of the second brood emerged between July 26 and August 2 and the last between August 20 and 29. The life of the adult varied from 4 to 8 days, the average being 6.8 days.

Copulation lasts from 5 to 7 hours. The pre-oviposition period varied from 2 to 3 days with an average of 2.3 days. The average number of eggs deposited per female beetle of the second brood was 59.3—ten females depositing 593 eggs. The maximum number of eggs deposited by a single female was 62. The life-cycle of the second generation varied from 39 to 53 days with an average of 48.7 days.

Third Generation.—During 1938–41, the first eggs of the third generation were deposited between July 28 and August 4 and oviposition ended between August

TABLE I. *Life-History Data of*

Year	First eggs deposited on	Oviposition ended on	Incubation (hours). Range— Mean	Hatching of eggs		Feeding period of larvae (days). Range Average
				Commence- ment	End	
FIRST						
1938	20. IV	19. V	34-60	23. IV	20. V	27-35
1939	26. IV	23. V	29-65	28. IV	24. V	25-32
1940	29. IV	27. V	30-69	30. IV	28. V	26-36
1941	18. IV	20. V	26-71	21. IV	22. V	29-38
						29.4
SECOND						
1938	12. VI	9. VII	28-49	14. VI	10. VII	26-34
1939	16. VI	7. VII	23-50	18. VI	8. VII	23-31
1940	14. VI	16. VII	21-54	16. VI	17. VII	27-35
1941	9. VI	12. VII	30-59	11. VI	13. VII	23-33
						27.3
THIRD						
1938	31. VII	22. VIII	25-50	2. VIII	23. VIII	23-30
1939	4. VIII	29. VIII	22-45	6. VIII	30. VIII	25-33
1940	2. VIII	31. VIII	20-48	4. VIII	1. IX	21-29
1941	28. VII	28. VIII	29-55	30. VII	29. VIII	27-33
						24.8
FOURTH						
1938	18. IX	12. X	28-59	20. IX	13. X	25-30
1939	26. IX	21. X	30-63	28. IX	23. X	23-28
1940	21. IX	15. X	33-69	22. IX	17. X	22-29
1941	24. IX	18. X	25-57	25. IX	20. X	24-31
						25.7

22 and 31. The incubation period of the eggs varied from 20 to 55 hours with an average of 42 hours. During the four years, eggs commenced hatching between July 30 and August 6 and finished hatching between August 23 and September 1. The feeding period of the larvae ranged from 21 to 33 days with an average of 24.8 days. The pre-pupation period varied from 3 to 6 days with an average of 4.5 days. The first pupation took place between September 5 and 12 and the last between September 28 and October 4. The pupal period varied from 9 to 14 days with an average of 11.3 days.

During the four years, the first beetles of the third brood emerged between September 15 and 23 and the last between October 10 and 16. The life of the adult varied from 5 to 8 days, the average being 7.1 days.

Copulation lasts from 5 to 9 hours. The pre-oviposition period varied from 2 to 3 days with an average of 2.7 days. The average number of eggs deposited per female beetle of the third brood was 62.9—ten females depositing 629 eggs. The maximum number of eggs deposited by a single female was 66. The life-cycle of the third generation varied from 41 to 55 days with an average of 50.2 days.

Scolytus amygdali Guer (1938-41)

Prepupal period (1st, 2nd and 3rd generations). Prepupal and hibernation period (4th generation) (days). Range—Average	Pupation		Pupal period (days). Range—Average	Emergence of adults		Life cycle (days). Range—Average
	Commencement	End		Commencement	End	
GENERATION						
4-7 } 5-8 } 6-9 } 5-9 }	23. V 28. V 30. V 23. V	30. VI 26. VI 2. VII 6. VII	10-14 } 11-15 } 12-13 } 10-15 }	9. VI 13. VI 11. VI 7. VI	7. VII 5. VII 14. VII 10. VII	50-59 } 42-53 } 42-55 } 49-60 }
6.9			12.3			52.9
GENERATION						
3-6 } 4-7 } 3-5 } 5-7 }	20. VII 26. VII 22. VII 17. VII	12. VIII 9. VIII 17. VIII 14. VIII	8-11 } 7-10 } 8-12 } 9-12 }	29. VII 2. VIII 31. VII 26. VII	20. VIII 27. VIII 29. VIII 26. VIII	40-51 } 39-48 } 44-52 } 48-53 }
5.2			9.7			48.7
GENERATION						
3-5 } 4-6 } 3-6 } 4-5 }	5. IX 12. IX 9. IX 7. IX	28. IX 4. X 30. IX 1. X	10-12 } 11-11 } 9-11 } 10-14 }	15. IX 23. IX 18. IX 20. IX	10. X 16. X 12. X 15. X	43-50 } 45-53 } 41-49 } 46-55 }
4.5			11.3			50.2
GENERATION						
1938-39 } 174-179 } 1939-40 } 170-180 } 1940-41 } 166-177 } 1941-42 } 176-188 }	1939 } 8. IV 1940 } 10. IV 1941 } 14. V 1942 } 6. IV	10. V 8. V 11. V 5. V	14-17 } 13-16 } 12-15 } 14-16 }	25. IV 27. IV 16. IV 21. IV	22. V 25. V 18. V 20. V	210-225 } 207-229 } 200-221 } 214-231 }
177.3			14.6			211.

Fourth Generation.—During 1938-41, the first eggs of fourth brood were deposited between September 8 and 26 and oviposition continued up to October 12 and 21. The incubation period of the eggs varied from 25 to 69 hours with an average of 50 hours. The eggs commenced hatching between September 20 and 28 and continued to do so up to October 13 and 23. The feeding period of the larvae ranged from 22 to 31 days with an average of 25.7 days.

When full fed, the larva stops feeding and enlarges the end of its gallery and constructs a small chamber of sufficient size in which it hibernates and passes the winter. These chambers are embedded with frass to afford protection to the hibernating larvae from cold. During 1938, the first larva embedded itself in the chamber on October 16 and the last one on November 12. The dates on which the first larva stopped feeding and embedded in the chamber during 1939, 1940 and 1941 were October 21, October 23 and October 18 and the last one on November 19, November 16 and November 20 respectively. Securely enclosed in these chambers the larvae pass the winter until the approach of next spring season, when they change into pupae. The pre-pupation period including hibernation varied from 166 to 182 days with an average of 177.3 days. The first

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pupation took place between April 6 and 14 and the last between May 5 and 11. The pupal period varied from 12 to 17 days with an average of 14.6 days.

During the four years, the first beetles of the fourth brood emerged between April 16 and 27 and the last between May 18 and 25. The life of the adult varied from 6 to 9 days, the average being 7.9 days.

Copulation lasts from 7 to 10 hours. The pre-oviposition period varied from 2 to 3 days with an average of 2.8 days. The average number of eggs deposited per female beetle of the fourth brood was 69.7—ten females depositing 697 eggs. The maximum number of eggs deposited by a single female was 75. The life-cycle of the fourth generation varied from 200 to 231 days with an average of 211.9 days.

The life-history data are summarized in Table I (pages 90-91).

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BIOLOGY AND CONTROL OF *SCELODONTA STRIGICOLLIS* MOTS. (CHRYSEMELIDAE: COLEOPTERA)

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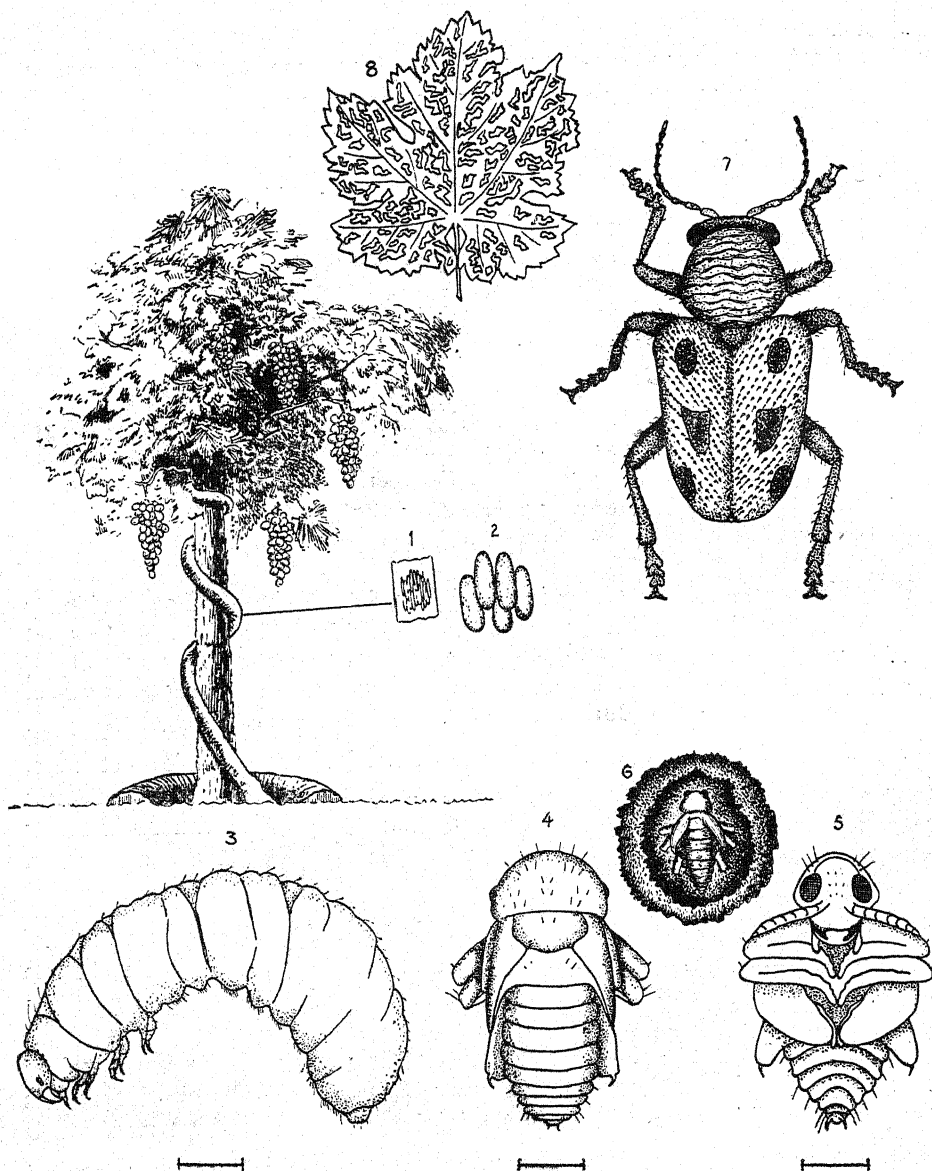
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I. INTRODUCTORY

Grape is the chief money crop in certain districts of the Bombay Presidency and the total annual value may come to about 25 lakhs of rupees. Of the total area of about 1,500 acres under grapes nearly 87% is in the Nasik district alone. Grape vine cultivation involves quite a number of problems of which the damage caused by the grape-vine beetles, *Scelodonta strigicollis* Mots., locally known as "Udadya", is of considerable significance. Investigations on this pest were, therefore, taken up in 1939 with a view to finding out suitable and effective control measures. This paper embodies the results of our observations at Nasik during the last six years under a scheme financed by the Sir Sassoon David Trust Fund.

Lefroy (1907) recorded this pest for the first time in India and gave a brief description of the adult, mentioning at the same time the considerable damage which it causes to pruned vineyards. He also referred to the trapping of the beetles at Nasik in tassels of dry sheaths of banana leaves. Fletcher (1914) stated that the life-history of the beetle was not known, though it was a serious pest of grape-vine in South India. Subramania Iyer (1921) observed that this pest was not found on vines trained in the local way but was serious in vineyards trained in the European manner, and was occasionally a serious pest. Rama-krishna Ayyar (1923) considered it the only specific pest of this crop. Later, Pruthi and Batra (1938) described the damage caused by this beetle in the N.W.F. Province. Our observations show that the adult beetles cause considerable havoc in the pruned vineyards by feeding on the sprouting buds particularly after the October pruning. Considering the amount of damage, it can be very well regarded as a serious pest of grape-vine.

Description of various stages*Scelodonta strigicollis* Mots.

1. Egg mass on the under surface of bark.
2. Egg mass magnified.
3. Full-grown grub.
4. Pupa—dorsal view.
5. Pupa—ventral view.
6. Pupa in earthen cell.
7. Adult.
8. Damaged leaves with characteristic elongated holes.

II. DISTRIBUTION AND HOST PLANTS

S. strigicollis has not been recorded so far from outside India. Fletcher (1917 and 1919) considered it as a common pest throughout India and Burma not only on grapes but also on mango inflorescences and wild species of *Vitis*. Robertson Brown (1917) noted it as destructive to the tender shoots of grapevines in the North-West Frontier Province. Ramchandrarao (1930) mentioned it as a pest on grape-vine in South India. In the Bombay province, however, it is commonly met with mostly in the central division (Nasik, Poona and Ahmednagar districts) and to some extent in the southern division (Bijapur and Dharwar districts). It has been observed to be monophagous on grape-vine even though it is also found to scrape the lower leaf surface of *pungara* trees (*Erythrina indica*).

III. LIFE-HISTORY

Copulation.—The beetles mate promiscuously. Successive copulations have been noticed during the egg-laying period, which commences by the middle of March and continues up to the middle of October. Usually, copulation starts about a month after the date of emergence of the beetles, especially in the case of the 1st brood.

Oviposition.—In nature, eggs are laid just beneath the bark of the vines and in the crevices formed due to its cracking, generally early in the evening in groups of 20 to 40. The preoviposition period may extend from 4 to 7 days. The egg-laying capacity of a female has been found to vary from 220 to 569 eggs in 10 to 14 instalments during its life of 8 to 12 months.

Egg.—Cigar shaped, creamy-white when freshly laid, changing to yellowish subsequently; chorion smooth, without sculpture; average measurements 0.92 mm. \times 0.25 mm. when freshly laid, 0.93 mm. \times 0.27 mm. before hatching.

Grub.—Eruciform; creamy-white; average measurements 1.07 mm. \times 0.27 mm. when newly hatched, 6.72 mm. \times 2.00 mm. when full grown. Head yellowish brown, slightly chitinized, measures 0.17 mm. \times 0.20 mm.; mouth parts mandibulate; eyes present; thoracic segments provided each with a fine pair of setae. Abdomen 10 segmented; legs short, each with a single claw.

Pupa.—Exarate, creamy-white; head deflexed; eyes brown; average length 4.22 mm. in male and 4.75 mm. in female; thorax well developed and prominent; abdomen white with two brown, recurved spines on the tibio-femoral joint.

Adult.—Shining, coppery colour on emergence, metallic bronze subsequently; average measurements 4.5 mm. \times 2.3 mm. Head prominent with two large compound eyes; antennae clavate, 11-segmented, average length 1.8 mm.; prothorax distinct, deflexed anteriorly and concave posteriorly; elytra on an average, 2.8 mm., decorated with six black patches, the central two being triangular in shape; abdomen well developed, greenish dorsally, brownish ventrally; female slightly bigger than the male; ovipositor flexible and pointed.

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Duration of various stages

Incubation period.—The incubation period, on the average, varied from 4.0 to 7.7 days during April to October. The minimum duration of 4 days was observed during April when the average temperature ranged from 80.5° F. minimum to 94.1° F. maximum with 37.7% average relative humidity. The maximum duration was, however, noticed during August when the average temperatures were 73.9° F. minimum and 77.4° F. maximum and relative humidity 78.3%. The percentage of hatching, on the whole, varied from 76.5 to 96.4 according to seasonal variations.

Larval stage.—Soon after hatching, the freshly emerged larvae drop down to the water basin and slowly burrow into the soil, feeding on the cortical layer of the roots where they remain for about 6 to 7 weeks. The larval stage under laboratory conditions varied from 34 to 45 days during the months, April to October (Averages in Appendix I). The shortest duration was noticed during June to August when the average temperatures were 73.9° F. minimum, 76.3° F. maximum and relative humidity 78.1%, whereas the longest was during September-October when the average temperatures were 75.9° F. minimum, 81.9° F. maximum and the average relative humidity 61.6%. Although the difference in the temperatures was not significant, slight variations in duration were observed.

Pupal stage.—Pupation takes place in an earthen cell. The pupal stage occupied 7 to 11 days and was found to vary as in the case of the egg stage with the temperature.

Duration of life-cycle.—In nature, the average duration of the life-cycle from egg to adult was 52.5 days, whereas in the laboratory it extended to 54.0 days (Appendix I). The average span of life of the adult beetle calculated from 110 cases under observation was 7 months and 22.5 days, the maximum being 15 months. In most of the cases, however, the beetles survived 9 to 12 months.

Sex-proportion.—Since the secondary sexual characters were not very prominent, beetles were collected from various localities and dissected in the laboratory to determine their sexes. In all about 2,500 beetles were examined during the years 1940 and 1942 and, on an average, the males and females were in the ratio of 1:1.25.

Behaviour

The adult beetles avoid extremes of temperatures and are positively thigmotropic; whereas the grubs are positively geotropic. When disturbed the beetles fall down, 'feigning death' and lie motionless for about 3 to 10 minutes.

Effect of irrigation on the duration of life-cycle

Potted vines under observation were infested with grubs of *S. strigicollis* Mots. Two sets of such plants, one receiving 750 c.c. of water and the other 1,500 c.c. on alternate days, were under experiment. It was observed that on an average, the duration of life-cycle under heavier irrigation was 44.3 days

and that under lighter one 58.8 days. The mortality of the grubs, however, was 75% and 90%, respectively.

Vertical distribution of various stages in the field

Observations were made from July to the end of October 1943. A number of soil samples were removed at random in layers of 1" thickness and within a two feet radius around the trunk of the vines. The samples were drawn from up to 8" depth and washed according to the method of Trehan (1945) and stages of the pest recorded. On an average, the number of larvae recorded per sample varied from 0.3 to 4.0 and the pupae 1.0 to 2.6. The adults were recorded from the first 1" layer, the pupae up to 3" depth while the larvae were found as deep as 7" (Appendix II).

IV. SEASONAL HISTORY

The hibernating beetles start their breeding activity from middle of March but feeding activity is more pronounced after April pruning. From May onwards, the beetles feed on tender shoots and leaves and start breeding actively. In general, the pest is active from the middle of March to the end of November, and there may be three to four generations during this period. But as the adults are long-lived and oviposition occupies from 1 to 3 months, the generations generally overlap. The pest hibernates in the adult stage under the bark of the vines and in crevices of the supporting plant and often inside the dried up leaves. Hibernation lasts from the beginning of December to the middle of March. Accordingly, in nature eggs are found from the middle of March to the middle of October, and larvae from May to November. The adults, however, are met with throughout the year.

V. NATURE AND EXTENT OF DAMAGE

Pruthi and Batra (1938) described the damage caused by this beetle in the North-West Frontier Province thus—"Early in March when young buds begin to sprout, they are either bored into or eaten up completely by these beetles. The damage is severe if the weather is rather warm for this time of the year. If a cold spell comes in at this time, the vines escape severe damage. This is probably why the early varieties escape the damage while late ones suffer heavily. Later, i.e., during July the beetles nibble the leaves, scratch the tendrils and eat the epidermis of branches. In autumn when more fresh leaves are out the beetles are again seen in large number eating the apical shoots, etc." Our observations at Nasik have shown that severe damage occurs when the buds start sprouting particularly after pruning in October. The damaged buds begin to bleed and fail to sprout well. Where the beetles are allowed to multiply unchecked, they bite canes as well. As a result, the tender shoots wither and drop down. Primarily, therefore, the damage is caused by beetles and secondarily it is presumed that the grubs also contribute to the damage by constantly feeding on the cortical layer of the roots although the grub cannot be regarded as a pest. To

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study this, two sets of potted vines were selected. In one set 25 grubs were liberated in each of the four pots and the other set of four was kept as control. In both the cases, the vines were practically uniform in growth at the time of liberating the grubs. It was noticed at the end of the experiment after 12 weeks that the average length of a shoot in the grub-infested vines was 5.10 cm. against 7.75 cm. in the control.

Our observations in the field on random vines have shown that damage by these beetles extends from about 11.0 to 31.0% in a fairly clean and well managed garden. The neglected vineyards, however, suffer still more heavily (Appendix III).

VI. CONTROL

The age-long local practice of trapping the beetles with banana tassels needed change and improvement. A good many mechanical as well as chemical control measures therefore, were tried during these investigations. A few that proved successful are given below:—

A. Mechanical

(i) *Removal of the loose bark of vines.*—Experiments were conducted in an area of 5 acres at the Ganeshkhind Fruit Experimental Station, Kirkee (Poona) and in 10 acres of a garden at Ozhar (Nasik), during 1944 and 1945. For each experiment, observations were made on 25 vines at random. Removal of loose bark after April pruning reduced the number of egg masses on an average by 57% and 63%, respectively in the two gardens. This ultimately resulted in reducing the beetle population by about 42% in both the vineyards (Table I).

TABLE I. *Mechanical control by removal of loose bark*

Locality	Year	Average No. of egg-masses per vine during one week		Percentage reduction in No. of egg-masses	Average No. of beetles per vine during one week		Percentage reduction in No. of beetles
		Before treatment	After treatment		Before treatment	After treatment	
Poona ..	1944	20.3	8.5	58.1	17.0	10.1	40.6
	1945	24.9	11.0	55.8	20.1	11.2	44.2
			Average ..	56.8		Average ..	42.4
Ozhar ..	1944	25.0	9.3	62.8	19.0	11.55	39.2
	1945	23.1	8.5	63.2	18.4	10.1	44.8
			Average ..	63.0		Average ..	42.0

(ii) *Tray method.*—The habit of “feigning death” in the beetles was taken advantage of in devising this method of collection. A galvanized iron tray 3'× 2'× 4", wetted with kerosenised water, was dragged by one man below the vines in the early mornings of September before October pruning and the vines

were shaken by another man. The beetles, which fell into the tray, were collected and thrown into small buckets containing kerosenised water. Such large-scale trials were conducted in different gardens round about Nasik. In each garden vines practically uniform in growth were treated. The tray method yielded about seven times better results than the local tassel method.

TABLE II. *Comparative trials with tray and tassel methods*

No. of rounds		Day to Day collection of beetles by tray method before October pruning (A)	Day to Day collection of beetles by tassel method after October pruning (B)
1st	..	17,470	2,750
2nd	..	11,209	1,124
3rd	..	7,769	1,091
Average	..	12,149	1,655

In all 1,058 vines were under observation for each treatment.

(iii) *Umbrella method*.—During September 1943, a simpler and more effective method was devised by the junior-most author practically on the same principal as the tray method. An ordinary open umbrella was inverted and the inside wetted with kerosenised water. One man could operate by carrying it under the vines with his left hand and shaking the plants with his right hand. The beetles dropping down into the umbrella were collected and thrown in drums coated with some sticky material and half-filled with kerosenised water. This method was tried for a fortnight late in the evenings of May and June before the monsoon and in the mornings of September and October before pruning.

The efficacy of this method compared with the other mechanical methods was examined statistically from the data collected during 1943 to 1945 (Table III).

TABLE III. *Comparative efficacy of umbrella, tray and tassel methods (1943-45)*

Year	Area covered	Total number of beetles collected during 1st 10 days in October			General mean	S. E. of the treatment	Critical difference at 5% chance	Significance by "F" test
		Umbrella A	Tray B	Tassel C				
1943	$\frac{1}{30}$ th acre per acre	1871.6 56148	1464.0 43920	685.2 20566	342.6	57.0	118.1	Significant
1944	$\frac{1}{30}$ th acre per acre	2250.8 67524	1754.8 52644	1066.8 32004	845.4	124.1	276.5	Highly significant
1945	$\frac{1}{30}$ th acre per acre	2017.3 60519	1763.7 52911	785.9 23577	561.3	112.3	202.5	do

The umbrella method was found to be significantly superior to both the tray and tassel methods and the tray method significantly superior to the tassel method.

Further, the economics of the various mechanical control measures were worked out and the following results were obtained:

TABLE IV. *Cost of different mechanical control measures per acre*

Items	Treatments		
	Umbrella method	Tray method	Tassel method
Average No. of beetles collected per hour	945.2	797.3	242.4
Labour ..	2 men	2 men and 2 women	3 men or women
Material ..	2 Umbrellas, 2 buckets for water and 3 bottles of kerosene oil	2 trays, 2 small buckets and 3 bottles of kerosene oil	1500 tassels (to be replaced almost every year)
Time ..	2 hours	2 hours	1 hour
No. of rounds per day ..	One between 7 to 9 a.m.	One between 7 to 9 a.m.	Two to three, 8 a.m., 12 noon and 4 p.m.
No. of days ..	10-15 days before Oct. pruning	10-15 days before Oct. pruning	20 to 30 days after pruning
Rate of wages ..	Men 0-4-0 per round per day	Men 0-4-0 per round, women 0-3-0 per round	0-2-0 per round
Estimated cost of labour	Rs. 6-0-0 (12 days on an average)	Rs. 10-8-0 (12 days on an average)	Rs. 18-12-0 (25 days with 2 rounds)
Cost of material (pre-war)	*Rs. 2-0-0 for 2 umbrellas and 0-8-0 for kerosene oil	*Rs. 1-0-0 for 2 trays and 0-8-0 for kerosene oil	Rs. 7-8-0 for 1500 tassels
Total Expenditure ..	Rs. 18-8-0	Rs. 12-8-0	Rs. 26-4-0

* Calculations are made by considering the life of an umbrella to be 2 years and that of the tray 5 years.

B. Chemical

(a) *Stomach poison against beetles.*—An attempt was made to find out the possibility of combining a stomach poison with Bordeaux mixture which is usually used by the cultivators against mildew. For this purpose, sodium fluosilicate, lead arsenate and Paris Green were selected. Preliminary trials showed that the mortality with sodium fluosilicate was not appreciable. Attention was, therefore, paid to the remaining two insecticides and their significance was worked out statistically from the mean of 3 years' results obtained from the A B B A method with 1/30th of an acre for each plot.

TABLE V. *Dead beetles collected from six vines at random in each plot for three days after each spraying*

R I		R II		R III		R IV		R V		R VI	
A	B	B	A	A	B	B	A	A	B	B	A
31	72	34	22	35	65	65	34	27	57	46	19

N.B.—Average number of living beetles per vine at random before treatment was 83-4.

A. Spraying with lead arsenate, 2 lbs. in 100 gallons of water, Bordeaux mixture of 2-2-50.

B. Spraying with Paris Green, 1 lb. in 100 gallons of water, Bordeaux mixture of 2-2-50.

R. Replications—six.

Statistical analysis—

Mean difference	..	..	..	..	..	..	28.50
Standard error of mean difference	..	..	..	..	..	..	3.84
Fisher's "t" (observed)	..	..	..	..	..	..	7.42
Fisher's "t" (expected) for 1% chance	..	..	..	..	..	..	4.032
Fisher's "t" (expected) for 5% chance	..	..	..	..	..	..	2.572

The difference between the treatments was statistically significant and Paris Green yielded better results than others. The economics of both these treatments (Table VI) showed that Paris Green, besides being relatively more effective, was also cheaper.

TABLE VI. *Cost of chemical treatments per acre*

Particulars	Spraying lead arsenate with Bordeaux mixture	Spraying Paris Green with Bordeaux mixture	Remarks
Average quantity of spraying material	125 Gallons	125 Gallons	2 lbs. lead arsenate in 100 gallons B. M., 1 lb. of Paris Green in 100 Gallons Bordeaux mixture
Labour	2 men	2 men	
Time	4 hours	4 hours	
No. of sprayings	Three	Two	Residual effect in case of Paris Green lasted for 5 days and in lead arsenate 3 days
Cost of labour	Rs. 2-4-0	Rs. 1-8-0	
Cost of insecticides	for 3 sprayings Rs. 5-8-0	for 2 sprayings Rs. 3-8-0	Cost of Bordeaux mixture is not taken into account as it is sprayed against mildew in the usual course
Total cost of spraying	Rs. 7-12-0	Rs. 5-0-0	

Average mortality calculated from the initial population before and after treatments was 48.7% with lead arsenate and 87.8% with Paris Green.

"Indian J. Ent., 9"

VII. SUMMARY

Scelodonta strigicollis Mots. is one of the major pests of grape-vine and is serious in pruned vineyards. It is monophagous on the grape-vine, even though it is found to scrape the lower leaf surface of *pangara* (*Erythrina indica*). The adult causes considerable damage to the orchards after October pruning.

The beetles lay eggs under loose bark and in crevices of the vines. The eggs hatch within a week. The grubs after hatching drop down to the water basin, enter the soil and feed on the roots. The grub pupates in an earthen cell where it remains for one to one and a half weeks. The average duration of its life-cycle is about 52.5 days in the field and 54.0 days in the laboratory. The span of life extends from 9 to 12 months. There are about four generations in a year. Hibernation takes place in the adult stage from November to March. The adults are of shining coppery colour on emergence, turning to metallic bronze subsequently. They avoid extremes of temperature taking shelter under the loose bark and dried leaves. When disturbed, they fall down, lie motionless and 'feign death'.

Some of the mechanical methods of control yielded very satisfactory results. The 'Umbrella method' is quite effective and economical. The cost per acre was estimated to be Rs. 8-8-0 as against Rs. 12-0-0 by the tray method. Removal of bark of the vine after April pruning results in reducing the beetle population and the number of eggs.

Paris Green sprayed with Bordeaux mixture (2.2.50) gave promising results and the cost of spraying per acre was estimated to be Rs. 5.

VIII. ACKNOWLEDGEMENTS

The authors express their thanks to the Chairman and the Trustees of the Sir Sassoon David Trust Fund for their kind encouragement and generosity in financing the scheme at Nasik. Further, the facilities provided to the authors by the grape-growers of Nasik, Messrs. H. V. Gole and V. V. Barve, and Dr. Chitko are acknowledged with thanks.

Our thanks are also due to late Dr. V. G. Deshpande, Ph.D., former Professor of Entomology, College of Agriculture, Poona, for his guidance in the investigations carried out before 1942. The co-operation extended by Mr. S. R. Gandhi, Horticulturist to Government, Bombay Province, and his staff at the Ganeshkhind Fruit Experiment Station, Kirkee, was also very helpful.

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* Original not consulted, The reference is to the abstract published in the *Rev. app. Ent.*, A, 18: 1930.

APPENDIX I. *Duration of various stages of S. strigicollis* Mots., 1940-43
(Average of 5 representative life-cycles)

Year and month	Average duration of			
	Egg stage (days)	Larval stage (days)	Pupal stage (days)	Life-cycle (days)
1940				
March—May ..	4.6	40.6	7.6	52.8
June—August ..	5.8	39.8	9.6	55.4
September—November ..	5.6	42.2	8.4	56.2
1941				
March—May ..	4.6	40.0	7.6	52.2
June—August ..	6.6	34.6	10.4	51.6
September—November ..	5.4	42.0	8.4	55.8
1942				
March—May ..	4.4	39.6	7.4	51.4
June—August ..	6.6	36.8	10.4	53.8
September—November ..	5.2	43.2	8.4	56.8
1943				
March—May ..	4.4	38.4	8.4	51.2
June—August ..	6.8	36.6	10.0	53.6
August—October ..	5.6	41.6	9.6	56.8

N.B.—The average duration of life-cycle in the laboratory, therefore, was 54.0 days.

APPENDIX II. *Distribution of various stages of S. strigicollis at different depths*

Date	Stages of the insect	Average No. of stages found in 6" squares soil-sample, at depths				
		1"	2"	3"	4"	5"
1943 22-VII	g	..	..	2	..	..
	G	1	1	..	..	..
	P	..	..	..	..	..
	A	..	..	..	..	..
29-VII	g	..	..	1	..	..
	G	1	2	..	..	..
	P	..	1	1	..	..
	A	..	..	..	..	..
5-VIII	g	..	..	..	1	..
	G	1	1	..	..	..
	P	1	2	..	..	..
	A	1	..	..	..	..
12-VIII	g	..	..	..	..	..
	G	..	..	1	..	..
	P	..	2	..	..	..
	A	..	1	..	..	..
19-VIII	g	..	..	..	1	..
	G	..	1	..	..	..
	P	..	1	..	..	..
	A	..	..	..	..	..
26-VIII	g	..	..	..	..	..
	G	..	..	1	..	..
	P	..	..	..	..	..
	A	1	..	..	..	..
2-IX	g	..	..	..	..	1
	G	..	1	..	..	..
	P	..	1	1	..	..
	A	1	..	..	..	..
9-IX	g	..	..	..	..	..
	G	..	1	..	..	..
	P	..	2	..	..	..
	A	..	1	..	..	..
16-IX	g	..	..	..	..	..
	G	1	..	..	..	..
	P	..	1	1	..	..
	A	1	..	..	..	..
23-IX	g	..	..	..	..	..
	G	1	..	..	..	..
	P	..	3	..	..	..
	A	1	..	..	..	..

APPENDIX II—(Contd.)

Date	Stages of the insect	Average No. of stages found in 6" squares soil sample, at depth				
		1"	2"	3"	4"	5"
1943 30-IX	g	..	..	..	..	1
	G	..	1	..	..	..
	P	..	4	..	..	..
	A	2	1	..	..	..
7-X	g	..	..	..	..	..
	G	..	..	..	..	..
	P	..	1	..	..	..
	A	1	..	..	..	..
14-X	g	..	..	..	..	..
	G	..	..	0.5	..	..
	P	1	1	..	..	..
	A	1	1	..	..	..
21-X	g	..	..	..	..	..
	G	..	..	..	..	..
	P	1	..	..	..	..
	A	1	..	..	..	..
28-X	g	..	..	..	..	..
	G	..	..	..	..	..
	P	..	0.2	..	..	..
	A	1	..	..	..	..

N.B.—g., Small grubs ; G., Full grown grubs ; P., pupa and ; A., Adults.

Each week six samples were examined at random. Since there were only two records of the grubs for 6" and 7⁵ depths, they have not been represented in the Appendix.

APPENDIX III. *Percentage of viable buds completely damaged by S. strigicollis* Mots. in nature, at different places during 1943-45

Locality	Year	Percentage of damaged buds during different fortnights										Average % of damage
		After April pruning				Average % of damage	After October pruning					
		April		May			October		November			
		1st fort- night	2nd fort- night	1st fort- night	2nd fort- night		1st fort- night	2nd fort- night	1st fort- night	2nd fort- night		
Nasik*	..	1943	3.7	11.2	19.1	19.1	13.2	7.2	21.5	21.5	28.4	19.5
		1944	3.6	7.9	13.9	15.9	11.7	8.9	21.2	26.5	38.2	23.7
		1945	3.2	4.5	19.2	23.5	12.6	2.6	28.0	24.6	28.5	23.4
Ugaon*	..	1943	4.6	10.0	13.9	25.6	13.5	11.9	16.2	31.7	40.5	25.0
		1944	4.2	12.6	16.7	24.4	14.4	16.6	17.0	48.6	41.8	31.0
		1945	5.2	7.7	20.7	23.1	14.1	9.6	15.6	34.1	36.1	23.8
Pimpalgaon (Basawant) †	..	1943	4.0	7.9	14.0	18.1	11.0	10.5	14.2	24.2	27.4	19.0
		1944	5.4	8.5	16.0	19.7	12.5	8.5	15.4	18.5	36.6	19.7
		1945	3.7	9.6	19.3	19.3	12.9	14.8	16.4	17.7	28.2	19.2
Poona†	..	1943	3.0	7.8	15.1	18.7	11.3	9.3	14.3	18.2	19.7	15.3
		1944	3.2	9.7	15.0	19.5	11.8	9.4	16.8	17.4	20.6	16.3
		1945	4.0	7.6	16.3	18.9	11.7	8.4	15.3	15.9	19.5	14.71

* Upkeep of garden below normal. † Upkeep of garden normal.

SHORT NOTES AND EXHIBITS

The Relative Incidence of *Dacus ciliatus* Loew. and *D. cucurbitae* Coq. on Cucurbit Fruits at Kanpur

In 1937, Bhatia [*Indian J. Ent.*, 1 (1 & 2): 107-14] recorded *Dacus ciliatus*, a well-known pest of cucurbits in the Ethiopian region, infesting bottle gourd (*Lagenaria vulgaris*) in association with *Dacus cucurbitae*, at Delhi. In 1941, this fruit-fly was recorded by me [*Indian J. Ent.*, 3 (2): 340] infesting *torai* (*Luffa aegytiaca*) with *D. cucurbitae*, at Kanpur. From November, 1943 to November, 1944, I made observations on bottle gourd, *torai*, *sitaphal* (*Cucurbita moschata*), bitter gourd (*Momordica charantia*), *kakri* (*Cucumis utilissimus*), *khira* (*Cucumis sativus*), *tinda* (*Citrullus vulgaris* var. *fistulosus*) and *kundru* (*Cephalandra indica*) with a view to finding out the relative abundance of the two species infesting these crops during different seasons of the year.

From November, 1943 to March, 1944, the cucurbits, viz., *torai*, *sitaphal* and bottle gourd, were found attacked by *D. cucurbitae* alone. *D. ciliatus*, in association with *D. cucurbitae*, was found attacking bottle gourd, bitter gourd and *kakri* during April, though *D. cucurbitae* was still the dominant species. Bitter gourd had the highest proportion of *D. ciliatus* flies, while *torai* was still free from its attack. During May and June, however, the flies that emerged from the infested fruits of bitter gourd, *kakri*, *torai* and *sitaphal* were all *D. ciliatus*. In July and August again both the species were found attacking *torai*, bitter gourd and *khira*, though *D. cucurbitae* was the dominant species. From September to November, 1944, the proportion of *D. ciliatus* had considerably gone down except in case of *tinda* where it was found the dominant of the two species. To sum up, *D. ciliatus* is practically absent from cucurbit vegetables from December to March when *D. cucurbitae* alone attacks these fruits. It appears in April and is the dominant species during May and June. It continues to attack cucurbit fruits, in association with *D. cucurbitae*, from July to November, though in a very much decreased proportion.

A parasite, *Opius fletcheri* Silv. was reared from the infested fruits of *torai*, bottle gourd and *sitaphal* between July and January. The parasitisation was never more than 4.5%.

Kanpur.

P. L. CHATURVEDI.

NEW BOOKS AND MONOGRAPHS

Insect Pests.—By W. M. Clunie Harvey and Harry Hill. Pp. xi+347. London, H. K. Lewis and Co. Ltd., 1947, Second Edition. Price Rs. 11-6-0.

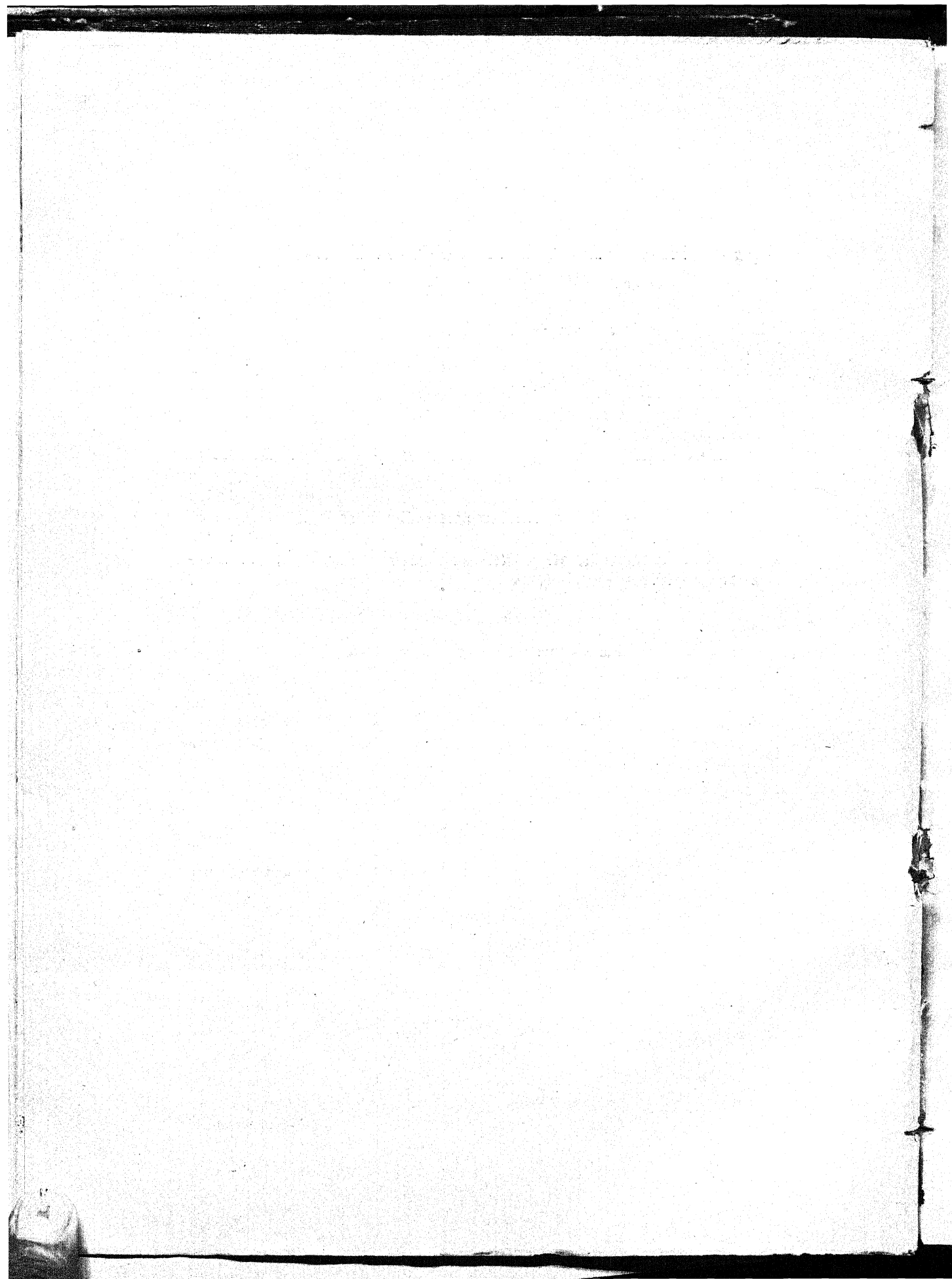
The name of the book leads one to expect more in some directions, less in others, than is actually given in it. The pests dealt with in it are only those which affect human health or human habitations or their furnishings. The first chapter is devoted to the physiology and characteristics of insects and the general methods of controlling such of them as are pests. Four out of sixteen chapters are devoted to legislative and chemical problems incidental to pest control, one to engineering problems, four to insecticides and one again to propaganda. The remaining five chapters deal with some types of insect and mite pests, important from the point of view of human health.

The book is ostensibly written for the use of those who live in temperate climates where the problems of insect pest control are not at their acutest. Although it is packed with much useful information, it contains some recommendations the practicability and value of which must be open to serious doubt, at least under tropical and semi-tropical conditions. For instance, it is difficult to see how mosquitoes can be controlled in buildings by catching them by means of hand nets or with fly papers (page 81). The habits of mosquitoes are different from those of house flies and while fly papers may be effective in one case, they may not be in the other. One of the merits of the book, however, is that it gives several alternative remedies against the pest, making it possible for any one to choose from them or to adopt more than one of them simultaneously. The book is fairly well illustrated which adds considerably to its usefulness.

K. B. LAL,

NEWS AND ANNOUNCEMENTS

The Government of the United Provinces has established a Plant Protection Service for controlling both pests and diseases of crops, fruit trees and stored agricultural products in the province. The Service started with a sanctioned staff of 74 of all grades which is to be progressively increased to 153 in the second year and 268 in the third. The headquarters of the Service are at Kanpur, in addition to which it would have had six Plant Protection Centres located in different parts of the United Provinces, where machines and pesticides and other Plant Protection equipment are to be stocked and staff posted for quick mobility and prompt action in times of pest and disease outbreaks. The cost of the Plant Protection Service, excluding the cost of control measures which also would be borne by Government, will be Rs. 10.71 lacs, recurring, spread over a period of 5 years, but the non-recurring expenditure originally estimated to be Rs. 45,900 is likely to be about Rs. 3.79 lacs by the end of 1949-50. The Service has been placed under the charge of the Entomologist to Government, U.P., with headquarters at Kanpur.



PROCEEDINGS OF THE ENTOMOLOGICAL SOCIETY OF INDIA, 1947

Delhi Branch—New Delhi

General—

Dr. E. S. Narayanan and Mr. Rattan Lal were elected President and Secretary of the Branch Society, respectively.

21st February

Communication—

The biology and control of *Myzus persicae* (Sulzer) as a potato pest—
Rattan Lal.

United Provinces Branch—Kanpur

General—

Mr. R. N. Singh and Mr. M. A. Aziz were elected President and Secretary of the Branch Society, respectively.

1st February

Communication—

Aims and objects of Plant Protection Service in India—K. B. Lal.

29th March

Communications—

Parasites of the cotton leaf-roller, *Sylepta derogata* Fabr.—Chhote Singh.

Possibilities of *Diacrisia obliqua* Wlk. becoming a serious pest in the U.P.—
Rampal Singh.

On oviposition in *Dinoderus*—M. A. Aziz.

Bombay Branch—Poona

General—

Dr. K. N. Trehan and Mr. G. M. Talgeri were elected President and Secretary of the Branch Society, respectively.

3rd February

Communication—

D.D.T. and other insecticides—P. J. Deoras.

19th February

Communication—

Insect transmission of plant viruses—P. M. Varma.

14th May

Communication—

Hormones in insects—P. R. Awati.

Bihar Branch-Pusa*General—*

The Branch was revived after four years. Mr. A. C. Sen and Mr. M. Imran were elected President and Secretary of the Branch Society, respectively.

14th May

Communication—

Ecological conditions favourable for the breeding of *Trichogramma minutum* Riley under north Bihar conditions—A. C. Sen.

Baluchistan Branch-Quetta*General—*

Mr. N. A. Janjua and Mr. S. M. Nasir were elected President and Secretary of the Branch Society, respectively.

26th March

Exhibits—

Larval galleries and egg chambers of shot-hole borer, *Scolytus amygdalae* Guer., on cherry, apricot and apple branches—Zunnur Ahmed.

Larval galleries of *Quettania coeruleipennis* Schw. on almond branches—Abdul Haq Qureshi.

The Indian Journal of Entomology

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STUDIES IN THE ASSOCIATION OF PLANT CHARACTERS AND PEST INCIDENCE: III. HARDNESS OF LEAF MIDRIB AND TOP BORER INFESTATION IN SUGARCANE*

By K. L. KHANNA, S. L. SHARMA and K. R. RAMNATHAN

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I. INTRODUCTION

In India, as in some other countries also, the top borer (*Scirpophaga nivella* Fabr.) is one of the major insect pests of sugarcane. Annual surveys at harvest carried out at Pusa from year to year (Khanna, 1944, 1945) have shown that it contributed to 50-60% of the total loss in weight due to all borer pests which amounted to 6-10% of the estimated crop, because stalks suffered most when infested with this pest. On stalk basis, it was found to attack easily 75% of the total number of stalks infested with borers.

In addition to the high percentage of infested stalks, the number of deaths in tillers caused by the top borer during the whole season has to be taken into consideration in estimating the total loss to the cultivator. Shoots attacked early in the season, i.e., up to July in Bihar, are killed outright (Fig. 1) and do not leave any trace of their having been formed at all, because by then, they consist only of soft tissues which are unable to stand the inroads of saprophytic organisms and physical deterioration and disintegration. The miller also comes in for his share of the loss as the juice of canes, the growing points of which have died, deteriorates to a great extent. The juice of Co 313 and Co 421 stalks attacked by top borers was found to contain at harvest respectively 5.48% and 4.26% less of total sugar than otherwise available in these varieties.

Among the methods of control, the importance of the introduction of a resistant variety can hardly be over-emphasised. Any easily determinable morphological or anatomical character, showing high correlation with resistance, would be obviously useful in selecting such a variety for general cultivation. Isaac (1939) considered that varieties having hard leaf midribs were less susceptible

* The first part, entitled 'Nature of leaf surface and mite attack,' appeared in the *Proc. Nat. Inst. Sci. India*, 13 (6), and the second part, entitled 'On the relationship between spindle length and varietal resistance to top borer attack in sugarcane,' was published in *The Indian Journal of Entomology*, 1946, 8 (2), 178-85.

to the top borer infestation than those with soft ones. The suggestion was taken up for detailed investigation by Thuljaram Rao and Venkatraman (1941). The former (1947) found that there was a fairly close relationship between the

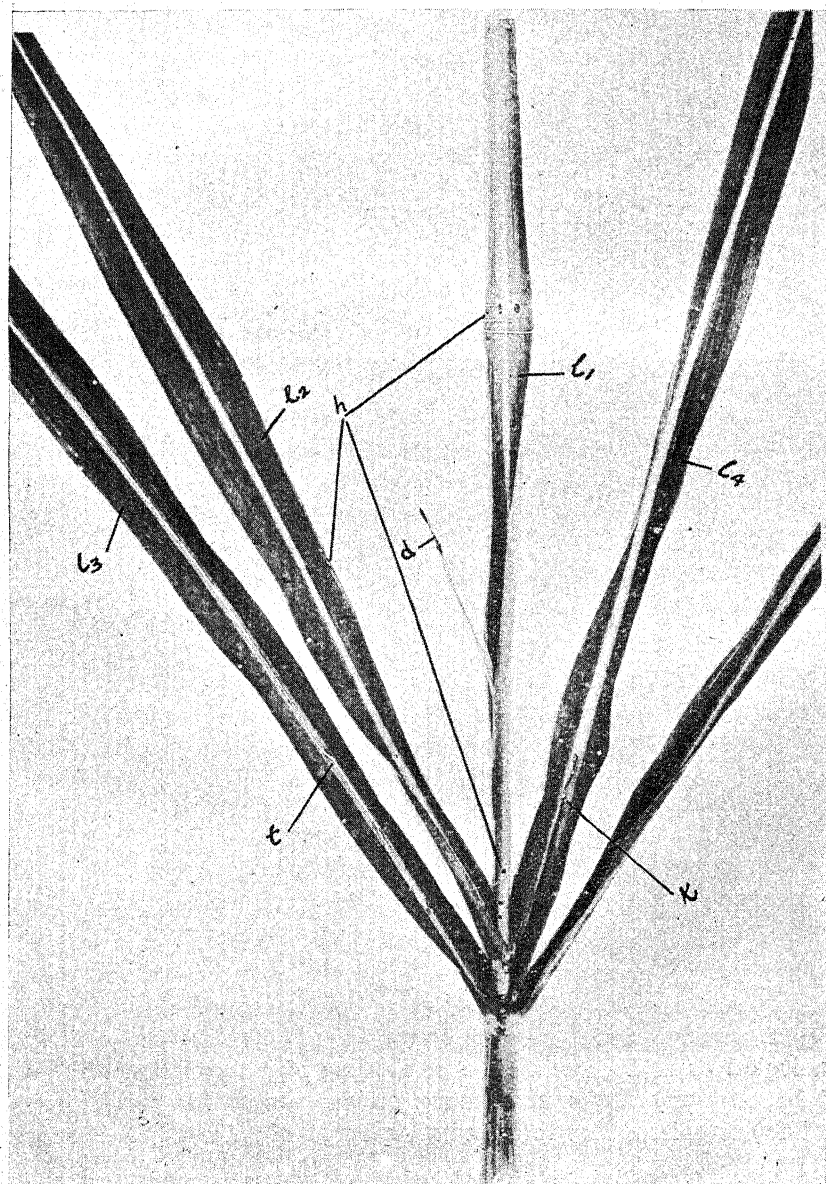


FIG. 1. Leaf-crown of a top borer-infested Sugarcane plant showing dead-heart (*d*) and characteristic shot-holes (*h*) in leaves (*L*₁, *L*₂). Borer tunnels (*t*) are clearly visible in leaves (*L*₃, *L*₄). In the former, the top borer entered through a lateral sector of the midrib.

amount of lignification in midrib, *i.e.*, the hardness of midrib, and the degree of resistance of a variety and that the former was an inheritable character.

In view of the importance thus given to the hardness of midrib as a character, accounting for resistance of a variety to top borer attack, a detailed study of this factor was taken up at the Pusa station, with a view to finding out (i) how far different varieties differed from one another as regards the hardness of their midribs, (ii) how far this character was stable under different environments and (iii) how far it was responsible for a variety's resistance to top borer attack. Khanna and Sharma (1947) found that the thickness of outer walls of long cells of the lower epidermis of a midrib was a fairly reliable index of its hardness as determined by a physical method except for varieties which were abnormal in one respect or another. The erratic behaviour of these varieties was easily understood when their anatomical structure was studied in detail. Although the method suggested by Khanna and Sharma was found to be good for general purposes, a detailed examination of the anatomical structure was deemed necessary for critical study.

In the present contribution, results of an intensive investigation into the problem as a whole are described.

II. MATERIAL AND METHODS

Material from seven varieties, namely Co 213, Co 285, Co 299, Co 313, Co 331, Co 421 and Co 513, covering a wide range of both the characters, was collected at Pusa in June and September, 1942, and in May and August, 1943 which periods coincided with the 2nd-3rd and 4th-5th broods in the seasonal cycle of the top borer.

Material from Co 213, Co 313 and Co 421 along with that of some of the other varieties was obtained once in 1942-43 and twice in 1943-44 about the same time from Shahjahanpur, Karnal, Lyallpur, Jorhat, Anakapalle and Patna (Table I).

TABLE I. *Varities received from different places*

Varieties	June 1942							Sept. 1942	May 1943					August 1943			
	Pusa	Karnal	Shahjahanpur	Anakapalle	Jorhat	Lyallpur	Patna	Pusa	Pusa	Karnal	Shahjahanpur	Anakapalle	Pusa	Karnal	Shahjahanpur	Anakapalle	
Co 213	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	..	
Co 285	X	X	X	..	..	X	..	X	X	X	..	..	X	X	..	..
Co 299	X	X	..	X	X	..	X	X	X	X	X	..	X	X	..	..
Co 318	X	X	X	X	X	..	X	X	X	X	X	X	X	X	X	X	
Co 331	X	X	X	X	X	..	X	X	X	X	..	X	X	X	..	X	
Co 421	X	X	X	X	X	X	..	X	X	X	X	X	X	X	X	X	
Co 513	X	X	..	..	X	..	..	X	X	X	..	..	X	X	..	..

X = material received and studied.

A three-inch piece covering the region between $\frac{1}{4}$ and $\frac{1}{5}$ of the leaf-length (Table II) where larva was usually found to enter was taken for sectioning and three such pieces formed a sample for each variety.

TABLE II. *Average length of standard leaf, average distance of point of entry of larva from transverse mark* and the latter as % of the former*

Variety	Length of leaf in cms.	Distance of the point of entry in cms.	Distance of the point of entry expressed as percentage of the leaf length
(1)	(2)	(3)	(4)
Co 205 ..	120.7 \pm 1.83	17.2 \pm 1.58 (25)	14.3
Co 210 ..	96.4 \pm 2.04	21.5 \pm 2.80 (12)	22.3
Co 213 ..	137.9 \pm 1.54	26.5 \pm 1.13	19.2
Co 281 ..	157.9 \pm 2.14	33.1 \pm 1.22	21.0
Co 285 ..	108.4 \pm 1.30	23.7 \pm 1.61 (20)	21.9
Co 290 ..	112.5 \pm 2.00	26.0 \pm 1.96 (10)	23.1
Co 299 ..	122.7 \pm 1.77	27.5 \pm 0.89	22.4
Co 313 ..	126.3 \pm 1.71	27.7 \pm 1.06	21.9
Co 331 ..	156.2 \pm 1.53	38.6 \pm 1.48	24.8
Co 356 ..	121.0 \pm 1.55	29.5 \pm 0.93	24.4
Co 385 ..	148.1 \pm 2.05	31.8 \pm 1.48	21.5
Co 393 ..	131.3 \pm 0.96	34.2 \pm 0.96	26.0
Co 395 ..	97.1 \pm 1.74	21.2 \pm 0.80	21.8
Co 419 ..	132.0 \pm 1.58	33.7 \pm 0.98	25.5
Co 421 ..	136.4 \pm 1.27	30.7 \pm 1.06	22.5
Co 508 ..	110.6 \pm 0.98	23.9 \pm 0.92	21.6
Co 513 ..	135.8 \pm 1.59	30.8 \pm 0.90	22.7
Sewari	75.1 \pm 0.92	15.6 \pm 1.78 (10)	20.7
(Nargori group)			
Maneria	83.6 \pm 1.22	14.8 \pm 1.95 (10)	17.7
(Pansahi group)			
Saralitha	124.1 \pm 2.37	24.8 \pm 1.38 (50)	20.0
(Saralitha group)			

* Transverse mark is the portion of leaf where lamina and sheath are joined together.

Note.—Column 2: Average of 50 measurements.

Column 3: Average of 100 measurements.—Where the number of leaves observed was less than 100, it is given in brackets.

Hand sections were cut and prepared into permanent mounts after staining with 1% Safranin solution in 50% alcohol.

The following characters of midrib were studied:—

1. (a) The total area of large vascular bundles calculated by multiplying their number and average size.

(b) The total area under sclerenchymatous cushions on which the medium sized vascular bundles were situated; calculated in the same way as (a).

2. (a) The thickness of walls of sclerenchymatous cells forming the sheaths of large vascular bundles.

(b) The thickness of outer walls of long cells in the lower epidermis.

3. The area of the midrib in cross-section.

4. (a) The vascular area index and (b) the cushion area index.

The average size of vascular bundles in each midrib was found out by multiplying the average radial and tangential axes (Fig. 2) obtained from

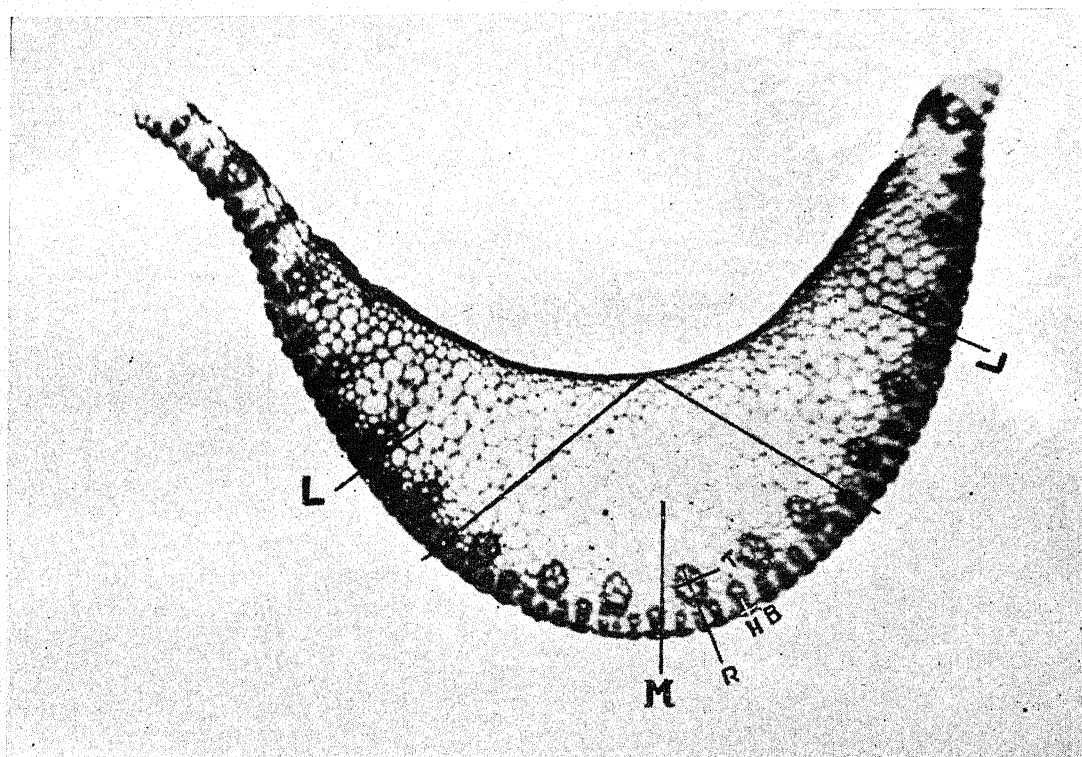


FIG. 2. T.S. of a midrib of Co 421 collected at Shahjahanpur in June 1942, illustrating its median (*M*) and lateral (*L*) sectors. It is harder in the former than in the latter portions. The radial (*R*) and tangential (*T*) axes of a vascular bundle and the base (*B*) and the height (*H*) of a sclerenchymatous cushion have also been shown ($\times 15$).

measurements of 10 vascular bundles (Khanna and Sharma, 1947) and similarly that of sclerenchymatous cushions which were more or less columnar in shape, by multiplying the length of the base and height. Usually in a midrib the number of vascular bundles and sclerenchymatous cushions ranged between 10-15; in cases where they were less than 10, all of them were measured.

Ten measurements of thickness of cell walls were taken in the middle convex portion of each midrib and each measurement in the case of epidermal cells represented the thickness of a single cell-wall while that for sclerenchyma, of two adjoining walls. The thickness of cell walls was expressed in the divisions of eye-piece micrometer, each of which was equal to 0.22μ .

The area of a midrib was found out by drawing its sketch with camera lucida on paper squared to $1/10$ th of an inch.

The indices for vascular and sclerenchymatous cushion areas were obtained respectively by dividing the area under vascular bundles and sclerenchymatous cushions by the area of a midrib in cross-section. They were, therefore, a measure of strengthening tissue per square unit. Since the indices were pure numbers, it was not necessary to convert the area of midrib into the same scale in which the other two were measured.

In the ultimate analysis, therefore, only characters 2 and 4 were considered.

The data on infestation of these varieties by top borer were collected brood-wise both during 1942-43 and 1943-44 at Pusa. But for other places such elaborate data were not available, though reports in general terms such as 'susceptible' or 'resistant' were received. Observations on infestation given in various reports of the Sugarcane Research Stations were gathered together to find out how a particular variety behaved from year to year in a particular locality.

III. OBSERVATIONS

A. *Anatomical Characters*: (i) *Varietal Differences*.—The data given in Table III showed that the differences between varieties were significant at 1% level in the case of the thickness of walls of the long cells of epidermis and of those forming vascular sheaths. Co 421 was a class by itself as it was significantly different from the next best, *i.e.*, Co 331. Although Co 213 came after Co 331 in respect of epidermal cell-walls, it was the least lignified when the thickness of sclerenchymatous cell-walls was considered, while the reverse was the case with Co 513. Of the remaining three varieties, Co 299 occupied an intermediate position, followed by Co 313 and Co 285. The varieties could, therefore, be arranged as follows in descending order of lignification, varieties within brackets being more or less equal.

Thickness of walls of long cells of epidermis.—Co 421, Co 331, Co 213 (Co 299, Co 285, Co 313) and Co 513.

Thickness of walls of cells forming vascular sheaths.—Co 421, Co 331, (Co 513, Co 299, Co 313), (Co 285, Co 213).

As regards the indices of area under vascular bundles and sclerenchymatous cushions, the differences between varieties were not so highly significant, less so for the former, as was the case with the thickness of cell walls. These indices were greatest in Co 285 which was not so distinctively different from the next in the list, *i.e.*, Co 513, as Co 421 was from Co 331 in respect of the thickness of cell walls. From the point of view of vascular area, Co 421, Co 299, Co 331 and Co 313 formed a group intermediate between Co 285 and Co 513 on the one hand and Co 213 on the other, while on the basis of the cushion area index, Co 313, Co 331, Co 213 and Co 421, lumped themselves together into one group, Co 299 being situated between this group and Co 513. These varieties might, therefore, be arranged in descending order of the indices as follows, varieties within brackets being more or less equal.

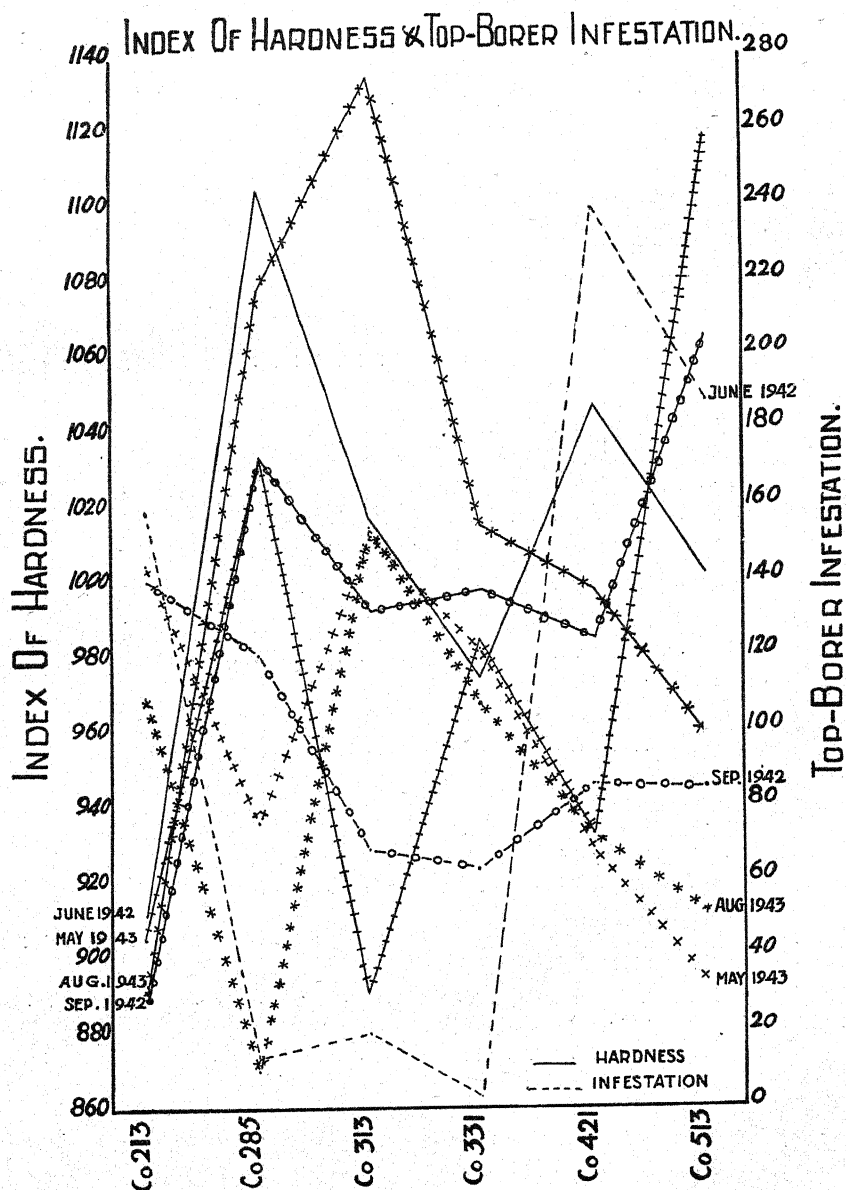
TABLE III. Anatomical characters of midribs of seven varieties collected at four periods during 1942-43 and 1943-44

Variety	Thickness of outer walls of epidermal cells				Thickness of sclerenchymatous cell walls				Vascular area index				Sclerenchymatous cushion area index			
	June 1942	Sept. 1942	May 1943	Aug. 1943	June 1942	Sept. 1942	May 1943	Aug. 1943	June 1942	Sept. 1942	May 1943	Aug. 1943	June 1942	Sept. 1942	May 1943	Aug. 1943
	(a) At Pusa				(b) At Karnal				(c) At Jorhat							
Co 213	22.3	21.1	20.7	21.2	27.0	24.7	26.1	17.2	6832.7	6743.3	7330.6	6840.4	583.2	503.2	564.1	497.0
Co 285	20.8	20.7	19.1	24.2	25.9	24.2	25.1	28.3	8035.6	7570.7	8685.8	7865.0	831.1	704.3	592.0	707.3
Co 299	20.5	19.6	20.7	20.8	27.2	26.7	26.4	27.6	7359.4	7237.0	9893.7	7078.1	601.3	741.1	723.2	541.9
Co 313	20.0	20.7	19.8	22.2	27.7	24.2	25.7	30.1	7794.2	7015.1	7475.2	8399.3	671.9	698.0	531.5	753.4
Co 331	22.8	21.4	22.3	22.3	29.6	27.6	29.0	28.2	7510.2	7156.1	8143.2	8143.2	577.9	656.1	590.1	559.9
Co 421	24.8	23.3	21.2	25.8	29.1	29.2	28.1	30.5	7630.4	7226.5	7694.5	7511.5	654.3	581.5	547.6	560.3
Co 513	19.5	19.8	21.0	21.2	26.9	25.9	25.8	27.5	7515.3	8113.1	9502.2	7232.4	684.9	698.1	740.2	583.8
General mean	21.6	20.9	20.7	22.5	27.6	26.1	26.7	28.5	7502.5	7295.0	8392.2	7581.0	657.8	954.7	627.0	600.7
C.D. at 1% level	1.73	0.77	1.47	2.02	1.60	1.03	2.53	1.51	..	..	1695.0	..	..	144.98	154.36	179.27
C.D. at 5% level	1.24	0.55	1.06	1.46	1.16	0.74	1.82	1.09	1793.67	748.2	1221.34	1007.66	198.18	104.46	111.22	129.17
Co 213	21.9	..	19.8	22.0	25.1	..	23.3	28.8	8581.9	..	7043.6	6594.4	601.5	..	525.1	524.6
Co 285	20.0	..	20.7	23.2	25.5	..	26.7	27.1	8691.3	..	9235.0	7940.6	869.0	..	729.5	781.6
Co 299	21.2	..	20.2	22.4	27.9	..	26.6	28.5	7910.7	..	6991.0	7530.7	883.7	..	499.3	612.0
Co 313	20.0	..	20.1	21.5	24.5	..	24.6	29.7	6944.7	..	7286.2	7176.3	607.9	..	167.4	584.9
Co 331	22.7	..	21.6	22.3	27.7	..	26.7	29.1	7781.9	..	7887.7	6300.5	604.3	..	568.2	454.6
Co 421	23.4	..	23.2	27.2	27.5	..	28.5	29.5	8151.7	..	8416.4	6794.4	713.1	..	621.8	503.5
Co 513	20.0	..	20.3	20.9	27.1	..	25.1	29.2	7580.0	..	8501.0	8108.8	680.4	..	649.0	631.1
General mean	21.3	..	20.9	22.8	26.5	..	26.2	28.9	7663.2	..	7908.7	7207.5	680.0	..	594.3	514.6
C.D. at 1% level	1.17	..	1.74	1.96	2.36	..	..	1.18	1075.77	..	1320.00	..	156.56	..	149.95	154.62
C.D. at 5% level	0.84	..	1.25	1.42	1.70	..	2.06	0.85	775.12	..	951.09	1238.39	112.81	..	108.04	111.41
Co 213	20.7	..	..	..	23.1	..	..	..	7442.0	..	..	..	642.7	..	..	..
Co 299	20.5	..	..	..	25.3	..	..	..	7966.8	..	..	..	712.6	..	..	..
Co 313	19.5	..	..	..	25.5	..	..	..	7631.6	..	..	..	638.5	..	..	..
Co 331	21.4	..	..	..	25.4	..	..	..	8430.1	..	..	..	659.7	..	..	..
Co 421	21.8	..	..	..	26.9	..	..	..	8244.4	..	..	..	614.4	..	..	..
Co 513	19.6	..	..	..	27.1	..	..	..	9566.3	..	..	..	657.4	..	..	..
General mean	20.6	25.5	8213.5	657.5
C.D. at 5% level	0.75	0.78	1693.32	101.37
C.D. at 1% level	1.05	1.09

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Vascular Area Index.—(Co 285, Co 513), (Co 421, Co 299, Co 331, Co 313) and Co 213.

Cushion Area Index.—Co 285, Co 513, Co 299, (Co 313, Co 331, Co 213, Co 421).



It is interesting to note that, apart from these differences, the spacing of vascular bundles in different portions of a cross-section of a midrib and in

different varieties was not the same. The bundles were spaced farther apart in the lateral sectors than in the middle of the cross-section in varying degrees in almost all varieties, as was clearly the case in Co 213 and Co 285, Co 313 and Co 421 (Plate I, Figs. 1, 2, 4 and 6). In the remaining three varieties, namely Co 299, Co 331 and Co 513, the difference in the spacing of vascular bundles in the median and lateral sectors was not so well pronounced (Plate I, Figs. 3, 5 and 7). Between varieties, the vascular bundles in Co 285 were closer to one another than they were in Co 331 and Co 421 (Plate I, Figs. 2, 5 and 6).

(ii) *Stability of the Anatomical Character : (a) Effect of localities on a variety in the same season.*—With a view to studying how far the magnitude of the anatomical characters dealt with in the last subsection varied from place to place, data on three varieties, namely Co 213, Co 313 and Co 421, which were received during all the three seasons from different places were statistically analysed (Table IV). It was found that all the four characters were the least stable in Co 421, because their values at one place were significantly different from their counterparts at another in many more pairs in this variety than in the other two varieties. In other words, the places did not group together, when considered with respect to Co 421, as they did in the case of the other two varieties, and where the groups were formed, they were smaller than those of Co 213 and Co 313. As regards the latter two varieties, Co 313 was less affected by places than Co 213 so far as the thickness of cell walls of both the tissues was concerned, while the reverse was the case for the area-indices.

When lignification of all the three varieties was considered, it appeared that environmental factors at Shahjahanpur were least conducive to this process, while at Pusa they promoted the greatest amount of lignification, Karnal being intermediate between the two. At Anakapalle and Jorhat, walls of both the tissues were thinner than those produced at Shahjahanpur. On the basis of the amount of lignification found in the varieties studied these places could be arranged as follows: Pusa, Karnal, Shahjahanpur, Anakapalle and Jorhat.

For the vascular and cushion area indices, Anakapalle showed the smallest indices, which in other words meant that the area of midribs was proportionately larger in cross-section at Anakapalle than at the other four places. The latter, however, did not show any consistent behaviour. These places arranged themselves as follows in the descending order of indices:

Vascular Area Index.—Pusa, Karnal, Shahjahanpur, Jorhat and Anakapalle.

Cushion Area Index.—Jorhat, Shahjahanpur, Karnal, Pusa and Anakapalle.

In addition to these differences found in the anatomical make-up of midrib, gross changes in its size were brought about when the same variety was grown at different places. The area of cross-section of a midrib of Co 213 and Co 313 was greater at Karnal than at Pusa and Shahjahanpur (Plate II, Figs. 1-6). In the case of Co 421, however, such marked difference in the size of a midrib was not observed to exist (Plate II, Figs. 7-9).

TABLE IV. *Anatomical characters of three varieties at different places during three periods in 1942-43 and 1943-44*

Place	Epidermis			Sclerenchyma			Cushion area			Vascular area		
	Co 213	Co 313	Co 421	Co 213	Co 313	Co 421	Co 213	Co 313	Co 421	Co 213	Co 313	Co 421
(a) June, 1942												
Pusa ..	22.3	20.0	24.8	27.0	27.7	29.1	583.2	671.9	654.3	6682.7	7760.8	7620.4
Karnal ..	21.9	20.0	23.4	25.1	24.5	27.5	601.5	607.9	712.8	6581.9	6944.7	8151.7
Anakapalle ..	22.0	20.4	21.9	21.9	25.4	28.0	504.3	584.4	568.5	6093.6	6602.2	7503.1
Shahjahanpur ..	22.2	20.3	23.5	24.1	25.1	28.2	522.6	652.2	820.8	6232.5	6636.9	7905.0
Jorhat ..	20.7	19.5	21.8	23.1	25.4	27.0	642.7	658.9	614.4	7442.0	7631.6	8244.4
C.D. for Var. at 5%		0.44*			0.43*			45.3*			456.7*	
C.D. for Var. at 1%		0.59			0.57			60.9			615.0	
C.D. for Place at 5%		0.57*			0.55*			58.4*			589.1†	
C.D. for Place at 1%		0.77			0.74			78.6			..	
C.D. for Interaction at 5%		0.99*			0.96*			101.2*			1021.6	
C.D. for Interaction at 1%		1.33			1.29			136.3			..	
(b) May, 1943												
Pusa ..	20.0	19.8	21.2	26.1	25.7	28.8	564.1	531.5	547.6	7330.6	6599.5	7694.5
Karnal ..	19.8	20.1	23.2	25.3	24.6	28.5	525.2	567.4	621.8	7034.6	7441.9	8416.4
Anakapalle ..	19.6	19.6	22.4	21.4	21.6	27.6	501.4	535.7	581.6	6116.8	7286.1	7611.0
Shahjahanpur ..	19.6	21.0	21.8	20.0	25.9	26.2	448.7	471.9	569.7	7090.3	7175.2	8126.0
C.D. for Var. at 5%		0.51*			0.84*			58.7			568.6*	
C.D. for Var. at 1%		0.69			1.14			..			770.6	
C.D. for Place at 5%		0.58			0.97*			67.7			655.8	
C.D. for Place at 1%		..			1.32			..			..
C.D. for Interaction at 5%		1.01*			1.69*			117.2*			1135.9	
C.D. for Interaction at 1%		1.37			2.29			..			..
(c) August, 1943												
Pusa ..	21.2	22.2	25.8	27.2	30.1	30.5	497.9	753.4	560.3	6840.4	8066.0	7511.5
Karnal ..	22.0	21.5	27.2	28.8	29.7	29.5	524.6	585.6	503.5	6594.9	7176.3	6741.1
Shahjahanpur ..	20.9	20.6	25.2	26.1	25.7	24.6	605.1	687.4	573.4	7248.1	6179.8	7015.4
C.D. for Var. at 5%		1.16*			1.16*			72.7*			694.6	
C.D. for Var. at 1%		1.58			1.59			..			..
C.D. for Place at 5%		1.16*			1.16*			72.7			694.6	
C.D. for Place at 1%		1.58			1.59			..			..
C.D. for Interaction at 5%		2.00			2.01			125.87			1203.2	
C.D. for Interaction at 1%		..			..			..			..

* Highly significant.

† Significant.

(b) *Effect of seasons on a variety at the same place.*—The effect of season on the development of the anatomical characters could not be studied comprehensively because only three varieties were available in all the three seasons and that too at Pusa, Karnal and Shahjahanpur only (Table V).

TABLE V. *Effect of season on the anatomical characters of midrib of three varieties of sugarcane*(a) *Thickness of outer walls of long cells of lower epidermis*

Season:	June 1942			May 1943			August 1943		
Varieties :	Co 213	Co 313	Co 421	Co 213	Co 313	Co 421	Co 213	Co 313	Co 421
Pusa	.. 22.3	20.0	24.8	20.7	19.8	21.2	21.2	22.2	25.8
Karnal	.. 21.9	20.0	23.4	19.8	20.1	23.2	22.0	21.5	27.2
Shahjahanpur	.. 22.2	20.3	23.5	19.6	21.0	21.9	20.5	20.6	25.2
C. D.	at 1% level			at 5% level					
For one factor	0.62			0.47					
For two-factor interaction	1.09			0.81					
For three-factor interaction	1.88			1.41					

Remarks.—Differences due to varieties and seasons and interaction between seasons and varieties were significant at 1% level.

(b) *Thickness of walls of sclerenchymatous cells forming vascular sheaths*

Season:	June 1942			May 1943			August 1943		
Varieties :	Co 213	Co 313	Co 421	Co 213	Co 313	Co 421	Co 213	Co 313	Co 421
Pusa	.. 27.0	27.7	29.1	26.1	25.7	28.8	27.2	30.1	30.5
Karnal	.. 25.1	24.5	27.5	25.7	24.6	28.5	23.8	29.7	29.5
Shahjahanpur	.. 24.4	25.1	28.2	20.0	25.9	26.2	26.1	25.7	28.6
C.D.	at 1% level			at 5% level					
For one factor	0.68			0.51					
For two-factor interaction	1.18			0.89					
For three-factor interaction	2.05			1.54					

Remarks.—Differences due to all the three factors and interaction between varieties and places and interaction of the three factors were significant at 1% level while the interaction between seasons and varieties was significant only at 5% level.

(c) *The Vascular Area Index*

Season:	June 1942			May 1943			August 1943		
Varieties :	Co 213	Co 313	Co 421	Co 213	Co 313	Co 421	Co 213	Co 313	Co 421
Pusa	.. 6683	7794	7621	7331	7475	7695	6840	8066	7512
Karnal	.. 6582	6945	8152	7044	7246	8417	6595	7176	6795
Shahjahanpur	.. 6233	6637	7906	7090	6600	8124	7248	6180	7015
C.D.	at 1% level			at 5% level					
For one factor	441.9			331.6					
For two-factor interaction	766.0			574.9					
For three-factor interaction	..			996.9					

Remarks.—Only differences due to varieties and interaction between varieties and places were significant at 1% level, while those due to places and interaction between varieties and seasons were significant at 5% level.

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(d) *The Cushion Area Index*

Season:		June 1942			May 1943			August 1943		
Varieties:		Co 213	Co 313	Co 421	Co 213	Co 313	Co 421	Co 213	Co 313	Co 421
Pusa	..	583	672	654	564	532	548	498	753	561
Karnal	..	602	608	713	525	567	622	525	525	503
Shahjahanpur	..	523	652	821	448	472	570	605	587	578
C.D.	..	at 1% level			at 5% level					
For one factor	..	51.3			38.5					
For two-factor interaction	..	88.9			66.7					
For three-factor interaction	..	..			115.7					

Remarks.—Differences due to varieties and seasons and their interaction were significant at 1% level while those due to interaction between varieties and places were significant at 5% level.

For obvious reasons samples collected in June, 1942 were not comparable with those of August, 1943. They, together with the collections of May, 1943, when sugarcane crop was more or less at the same stage of growth, were studied to find out how far the magnitude of the characters varied from year to year. Similarly a comparison of the May and August samples gave an insight into the differences prevailing in their magnitude at those periods in 1943-44 season. Data given in Table V were statistically analysed and the differences significant at various levels are given in Table VI.

TABLE VI. *Significance of differences in the magnitude of the four anatomical characters of midribs*

Place	Co 213				Co 313				Co 421			
	Thickness of epidermal cell walls	Thickness of sclerenchymatous cell walls	Vascular Area Index	Cushion Area Index	Thickness of epidermal cell walls	Thickness of sclerenchymatous cell walls	Vascular Area Index	Cushion Area Index	Thickness of epidermal cell walls	Thickness of sclerenchymatous cell walls	Vascular Area Index	Cushion Area Index
(a) June, 1942 and May, 1943												
Pusa	.. xx	.. xx	xx	—	—	xx	—	xx	xx	—	—	xx
Karnal	.. xx	.. x	xx	xx	—	—	—	x	—	xx	—	xx
Shahjahanpur	.. xx	.. xx	xx	xx	xx	xx	—	xx	xx	xx	—	xx
(b) May, 1943 and August, 1943												
Pusa	.. —	.. x	—	x	xx	xx	x	xx	xx	xx	—	—
Karnal	.. xx	.. xx	—	—	.. xx	xx	—	—	xx	x	xx	xx
Shahjahanpur	.. x	.. x	—	xx	—	—	—	xx	xx	xx	xx	—

xx Significant at 1% level.

x Significant at 5% level.

— Not significant.

From Table VI it would appear that in the case of Co 213, out of 12 pairs (3 places \times 4 characters), 10 were significantly different at 1% and one pair at 5% level, while for Co 313, only 5 pairs were significantly different at the former level and 1 pair at the latter. Co 421 had only 7 pairs significantly different at 1% level. It might, therefore, be inferred that the development of the four anatomical characters at more or less the same stage of growth was most amenable to seasonal variations in the environment in Co 213 and least so in Co 313, Co 421 being intermediate between the two but nearer Co 313.

When the effect of environmental variations due to seasons on individual characters was considered, it was found that the vascular area index was the least and the cushion area index the most affected. The thickness of cell walls of both the tissues was more or less as much influenced by season as the cushion area index.

When the development of these characters at different stages of plant growth within the same season was considered, it was found that differences due to stages of growth were least prominent in Co 213, as they were significantly different only in 4 pairs at 1% level and in three pairs at 5% level, whereas in Co 421, the thickness of cell walls of both the tissues was significantly different at 1% level at all the three places in May and August, 1943. Differences found to exist in the other two characters also were equally significant at Karnal, but not so at Pusa even at 5% level, while at Shahjahanpur only vascular area index was significantly different at 1% level, cushion area index being not so at all, in May and August, 1943.

As regards individual characters, the thickness of cell walls of both the tissues was the most affected by the stage of plant growth and the vascular area index the least, the cushion area index occupying an intermediate position.

The anatomical characters and varieties as influenced by seasonal changes might, therefore, be graded in descending order of variability as follows:

Environmental changes due to different seasons.—Thickness of cell walls in both the tissues, cushion area index, vascular area index.

Co 213, Co 313 and Co 421.

Environmental changes within the same season.—Thickness of cell-walls, cushion area index, vascular area index.

Co 421, Co 313 and Co 213.

It would, therefore, appear that of all the four characters, vascular area index was the most stable, and thickness of cell walls the least, so far as the seasonal changes were concerned.

(c) *Interaction of two factors:* (i) *variety and place.*—When the interaction between variety and place was studied, Co 213 and Co 313 were found to form big groups in respect of all the four characters, between themselves and also with Co 421 for the area-indices. Thus in June, 1942, Co 213 at Pusa, Karnal

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and Jorhat was not significantly different from Co 313 at Anakapalle, Shahjahanpur, Jorhat and Pusa so far as the index of cushion area was concerned. Similarly in May, 1943, the vascular area index in Co 213 at Pusa, Karnal and Shahjahanpur was more or less the same as in Co 313, at Shahjahanpur, Anakapalle and Karnal and also in Co 421 at Anakapalle, Pusa and Shahjahanpur.

For the other two characters, namely the thickness of walls of the epidermal cells and of cells forming the vascular sheaths, Co 421 segregated into groups of its own as distinct from those of Co 213 and Co 313, which between themselves formed groups smaller than those formed for area-indices. This showed that the vascular area and the area under sclerenchymatous cushions were not as much affected by the change of place as thickness of cell walls, which conclusion was quite plausible on theoretical grounds also. The differences due to the interaction of variety and place were significant at 1% level for the thickness of both the tissues in June, 1942 and May, 1943 and for cushion area index in June, 1942 only. Vascular bundles were not affected.

(ii) *Variety and season*.—Observations made on the interaction between variety and place were found to hold good in broad outline for the interaction of variety and environmental variations within the same season as also for those due to different seasons. The interaction between variety and season was significant at 1% level for the thickness of epidermal cell walls, and significant at 5% level for the other three characters. As already stated before, the thickness of cell walls in both the tissues and the vascular area index were respectively the most and the least variable due to seasonal influences.

(d) *Interaction of the third order* (variety \times place \times season).—The differences due to single factors were obliterated when the interaction of the three factors was taken into consideration, but there was a tendency on the part of Co 421 to gravitate to one extremity so far as the thickness of cell walls and vascular area index were concerned. Although there was no such segregation of Co 213 and Co 313 regarding these characters, Co 213 was farther away from Co 421 from the point of view of vascular area index and Co 313 from that of the thickness of cell walls. As regards the cushion area index all the three varieties were mixed up.

The effect of the interaction of these factors on individual character was more pronounced in the case of the thickness of cell walls of both the tissues, more so for the epidermal cell wall, than in that of the area indices. The vascular area index was the least variable of all the four characters.

B. *Infestation by Top Borer*: (i) *Varietal behaviour*.—Observations made at Pusa, Karnal and Jorhat on the top borer infestation of the sugarcane varieties studied for the anatomical characters of their midribs are given in Table VII. It would appear from Table VII (a) that Co 299 and Co 513 were found to be consistently the most resistant varieties except in 1937–38. Co 213 came next in 1940–41 and 1941–42, but in 1937–38 it had the highest percentage of infested

TABLE VII. (a) Infestation of sugarcane varieties by top borer at different places
(% stalks infested)

Variety	Pusa				Karnal			Jorhat		
	1937-38	1940-41	1941-42	1942-43	1939-40	1940-41	1942-43	1939-40	1940-41	1941-42
Co 213	7.9	11.2	14.0	28.0	..	..	55.8	..	..	..
Co 285	..	..	..	..	17.9	67.1	..	..	..	..
Co 299	4.2	9.8	9.0	13.5	..	..	38.3	..	..	..
Co 313	4.5	18.0	19.0	17.0	20.7	78.1	41.6	28.0	17.0	15.0
Co 331	2.9	24.0	27.0	26.0	13.4	51.70	35.7	..	..	..
Co 421	4.0	18.0	22.0	29.0	11.3	57.3	22.1	25.0	12.0	13.0
Co 513	6.7	9.0	13.0	18.0	..	..	..	..	..	..

stalks and more or less equally so in 1942-43 also. Co 313 occupied an intermediate position while Co 331 and Co 421 were the least resistant of the lot in 1940-41, 1941-42, 1942-43. These varieties, therefore, on the basis of four years' record, might be arranged in order of descending resistance as follows so far as Pusa was concerned:

Co 299, Co 513, Co 213, Co 313, Co 421 and Co 331.

At Karnal Co 421 was found to be the most resistant variety, followed by Co 331 and Co 313. On the basis of two years' data, Co 285 might be regarded more or less as susceptible as Co 313. When these varieties were arranged in order of descending resistance at Karnal they would appear as follows:

Co 421, Co 331, Co 313 and Co 285.

For four years (1939-40 to 1942-43), Co 313 was found to be more susceptible than Co 421 at Jorhat.

Infestation data collected monthly for two seasons (1942-43 and 1943-44) at Pusa, and for three seasons (1939-40 to 1941-42) at Karnal (Table VII b) showed that no variety was found to be either consistently the most resistant or the most susceptible at Pusa. It may, however, be stated Co 213 and Co 313 had greatest infestation three times each out of 8 observations, while Co 331 was found to be the most resistant on three occasions, and Co 285 and Co 513 on two occasions each.

At Karnal where continuous observations were available for Co 313 and Co 421, it might be stated with much justification that Co 421 was more resistant than Co 313, while on the basis of one year's data (1941-42) Co 213 might be regarded as more susceptible than both of them, and Co 299 the most susceptible of all the varieties studied.

It would therefore appear that not only the varieties were not consistent in their behaviour to top-borer attack at different places, but also their resistance varied from season to season and from year to year at the same place.

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(ii) *Entry of larva.*—Data collected on six varieties to study the entry of larva into the leaf midrib (Table VIII) showed that in 90% or more cases, in all the varieties at Pusa, larvae bored holes on the lower surface which was the dorsal surface with reference to the axis of the sugarcane plant, while at Byreah (North-West Champaran) entry through the upper surface ranged between 10–24%, the extremes, respectively, being occupied by Co 513 and Co 356.

TABLE VIII. *Mode of entry of the top borer larva at Pusa and Byreah (Champaran)*

Variety	Place of collection	Mode of entry		Entry holes per 100 leaves
		Dorsal	Ventral	
		%	%	
Co 313	.. Pusa	99.0	1.0	104.0
	Byreah	83.6	16.4	107.7
Co 356	.. Pusa	94.0	6.0	100.0
	Byreah	75.8	24.2	121.2
Co 393	.. Pusa	97.2	2.8	105.0
	Byreah	76.6	23.4	130.2
Co 395	.. Pusa	89.5	10.5	105.0
	Byreah	86.8	13.2	116.7
Co 508	.. Pusa	99.0	1.0	103.0
	Byreah	80.9	19.0	112.5
Co 513	.. Pusa	96.1	3.9	102.0
	Byreah	89.7	10.3	122.4

Note.—The leaf surface dorsal with respect to the axis of the plant corresponds to its lower surface and the ventral to the upper one.

As regards the actual situation of the entry-hole, it was found (Table IX) that a majority of the entries were sideways and that only 30–45% of them were situated in the median portion of the midrib (Fig. 1). Its position did not appear to have been influenced in any way by varietal differences in the anatomical make-up of a midrib.

TABLE IX. *Mode of entry of the top borer larva into the midrib of five sugarcane varieties during 1943–44 and 1944–45*

Variety	Year	Mode of entry		Point of entry	
		Dorsal %	Ventral %	Sideways %	Median %
Co 313	.. 1943–44	80	20	36	64
	1944–45	98	2	59	41
Co 331	.. 1943–44	98	2	62	38
	1944–45	96	4	62	38
Co 421	.. 1943–44	92	8	54	46
	1944–45	91	9	59	41
Co 508	.. 1943–44	98	2	66	34
Co 513	.. 1944–45	100	0	63	37

Preference on the part of larva for boring through lateral portion (Fig. 1) of a midrib suggested that a definite factor was operating. So the thickness of sclerenchymatous cell walls forming the vascular sheaths was compared in the two portions and it was found that the differences between these portions as regards this character were highly significant in all the three varieties (Table X).

TABLE X. *Average thickness of sclerenchymatous cell walls in lateral and median portions of a midrib*

Portion		Co 213	Co 313	Co 421
Lateral	..	21.6	22.1	24.7
Median	..	26.1	25.7	28.8
S.E.	..	0.585	0.556	0.643
"t" value	..	5.44	4.58	4.51

Note.—In all the varieties, the difference between the averages for median and lateral portions is highly significant.

Moreover the vascular bundles as already noted earlier were spaced appreciably farther apart in lateral sectors than in the median one. It progressively decreased especially in Co 213 and Co 421 (Plate III, Figs. 1 and 4; 3 and 6) as one approached the axis of symmetry of the midrib. Even in Co 313, vascular bundles *a* and *b* (Plate III, Fig. 2) were closer to each other than *b* and *c* or *c* and *d*.

It would, therefore, appear that the lateral portion of a midrib was softer than its median portion and a top borer larva entered the midrib at a point where it met the least resistance.

IV. DISCUSSION

From the observations given in Section III, it would appear that varieties on the whole did not behave in any consistent manner so far as their anatomical characters and resistance to top borer were concerned. Of the three varieties studied in detail, Co 421 was influenced to the greatest extent by changes of the environment, both due to place and within the same season, but least affected by those prevailing from season to season, while Co 313, on the other hand, was the most stable so far as the variations due to places were concerned, but occupied an intermediate position as regards the seasonal changes. The behaviour of Co 213 to variations due to places was intermediate, while it was the most and the least affected respectively by the differences induced from season to season and by those within the same season.

Similarly, the varietal resistance to top borer infestation did not appear to be a fixed quality. Co 421 was found to be more resistant than Co 313 at Karnal, while at Pusa the reverse was the case. Nor was the behaviour of a variety

consistently the same at the same place. Thus at Pusa Co 213 was found to be more resistant than Co 313 in 1940-41 and 1941-42 but less so in the succeeding year and in 1937-38. Also observations on these varieties made month after month did not fit in any pattern of a consistent behaviour.

As regards the individual characters, the varietal differences were most pronounced in the thickness of the cell walls of both the tissues and least so in the case of vascular area index, the cushion area index being more or less midway, but nearer the vascular area index. Also it was the thickness of cell-wall which was most affected by the changes in the environment brought about by places as well as by seasons both within the same season, and from one season to another. The vascular area index was the least variable character, the cushion area index being more akin to this than to the thickness of cell walls.

Thus in a phenomenon in which all the three components, namely the individual anatomical characters, the variety as a whole and its behaviour to top-borer infestation, varied in a most erratic manner, much correlation between the former two, on the one hand and the latter on the other, was not likely to exist. To test this hypothesis an attempt was made to synthesise the four anatomical characters into an index of hardness of the leaf midrib of a variety and correlate it with the top borer infestation of the variety at that time.

Since all the characters were not of the same numerical magnitude they were first reduced to a scale comparable to one another and thus capable of being added up, by expressing their varietal averages as percentage of their respective general means. Again, since the role played by each character in imparting hardness to a midrib was not equally important for all of them, weightage was given to them on the basis of their stability and importance in the make-up of a midrib. Although no experimental evidence could be adduced on the latter, it might safely be stated that vascular area index was the most important of all the four characters and was in an overwhelming measure responsible for the hardness of leaf midrib. This, coupled with its great stability in various environments, would put it at par with the other three characters taken together. The cushion area index for similar considerations would be adjudged as of greater importance than the thickness of cell walls in both the tissues taken together which were found to be influenced to the greatest extent by changes in the environment. On these considerations, vascular area and cushion area indices were given respectively 5 and 3 times the weightage of the thickness of cell walls of each tissue.

On the basis of these weightages the index of total hardness of a midrib was calculated as shown in Table XI, for varieties for which top borer infestation at the time of collection of the sample, was available.

The statistical analysis of the data presented below (Table XII and Graph) showed correlation coefficient for these 26 pairs of hardness-index and top-borer infestation to be of the order of -0.2685 which was negligible and non-significant.

TABLE XI. *Average magnitude of anatomical characters and index of total hardness in seven varieties (Pusa, 1942)*

Characters	Co 213	Co 285	Co 299	Co 313	Co 331	Co 421	Co 513	G. Mean
Vascular area index : average ..	6683	8036	7359	7794	7510	7620	7515	7503
% of the general mean	89.1	107.1	98.1	103.9	100.1	101.6	100.2	
Sclerenchymatous cushion area index : average ..	583	831	601	672	578	654	685	658
% of the general mean	88.7	126.4	91.4	102.1	87.8	99.5	104.1	
Thickness of epidermal cell wall : average ..	22.27	20.77	22.47	20.33	22.83	24.80	19.70	21.59
% of the general mean	103.2	96.3	94.9	92.6	105.6	114.8	91.2	
Thickness of scleren- chymatous cell wall : average ..	27.00	25.93	27.17	27.66	29.57	29.10	26.90	27.62
% of the general mean	97.8	93.8	98.6	100.4	107.3	105.4	97.5	
Total hardness :	912.6	1104.8	948.2	1018.8	976.8	1026.7	1002.0	

TABLE XII. *Total hardness of midrib and top borer infestation on stalk basis expressed as % of the mean at Pusa*

Variety	June, 1942		Sept., 1942		May, 1943		August, 1943	
	Index of hardness	Infestation	Index of hardness	Infestation	Index of hardness	Infestation	Index of hardness	Infestation
Co 213 ..	912.6	159.8	888.7	141.3	905.3	145.7	889.3	110.4
Co 285 ..	1104.8	13.4	1033.5	121.2	1032.4	76.3	1078.4	9.3
Co 299 ..	948.2	74.2	1031.7	133.7	..	..	..	..
Co 313 ..	1018.8	20.0	992.5	69.2	891.8	152.6	1134.5	155.8
Co 331 ..	976.8	3.1	999.3	64.4	984.1	122.9	1014.6	108.0
Co 421 ..	1026.7	240.2	985.3	86.5	931.1	69.4	997.1	72.6
Co 513 ..	1002.0	188.7	1069.8	85.6	1119.3	33.1	959.3	52.1

Correlation coefficient for these 26 pairs of observations was found to be -0.2685 which was not significant.

Besides, the hardness of leaf midrib, as judged by the anatomical method, did not appear to be an obstacle to the entry of the top borer larva because it was found to make a hole, more often than not, in the lateral soft portions of a midrib irrespective of whether the midrib was soft or hard as a whole.

It would thus appear that the resultant of the pest-host complex was not so simple as to be determined by the hardness of the leaf midrib alone which summed up its various components, not themselves very stable, in their entirety. Nor was it likely to be so, because the complex comprised two living organisms

which were susceptible to the influence of environment to the fullest possible extent. Moreover, relationship between the two was complicated by the fact that unlike the pest of which only one species was known to attack the sugarcane plant, there being no further known differentiation within the species itself similar to the physiologic races of some of the parasitic fungi, the host plant covered a very wide field. Top borer was found to infest in varying degrees, plants belonging to almost all the species of *Saccharum*, and certain species of allied genera, interspecific crosses and intergeneric hybrids. The behaviour of a host plant of such varied nature would naturally not be the same, when on theoretical grounds, the response of agrotypes of even the same parentage was not likely to be similar.

An analysis of the pest-host complex will show that apart from the highly variable anatomical structure of the leaf midrib, many other equally variable factors go into it. To begin with, the top borer moth is known to exercise a discrimination in oviposition which appears to be determined by the ease in laying eggs and some sort of chemotaxis. Eggs need a certain set of climatic conditions for them to yield larvae which bore their entry into midribs. The larvae, rather minute organisms, have to overcome, in order to produce dead-hearts, two main obstacles; the hindrance to their entry and the distance from the point of entry to the growing points of the cane stalks. That they need the right type of food and other conditions congenial to their metabolic activity and growth goes without saying.

Of the various constituent-factors of host-pest complex detailed above, only one, namely, the anatomical character was investigated by the authors and the correlation coefficient based on 26 pairs of observations on this character and infestation taken at Pusa during two seasons on seven varieties covering a wide range of both the features, was of the order of -0.2685 which was not significant at all. Thuljaram Rao (1947), on the other hand, concluded that the two attributes in sugarcane were highly correlated. The eight pairs of observations taken at Karnal gave a correlation coefficient as high as -0.9541 which was significant at 1% level. It is interesting to note that the eight varieties selected for study by him, aggregated at the two poles of an ellipse which would naturally be very narrow in view of the high value of the correlation coefficient.

Reasons for these diametrically opposite results are not far to seek. In the first place, he took, instead of actual observations, their averages which at times mask the true state of affairs. Secondly, the number of pairs on which he based his conclusions is only 8, too few for such types of investigations. And then, no intermediate grades of hardness of midrib or of top borer infestation were taken. Last but not the least, the influence of change in the environment on the host and pest was left out of consideration. Thuljaram Rao's observation that "there is correlation between the degree of resistance of a variety and the amount of lignification in the midrib" might be stated to hold good only under a limited

set of conditions, as it did for eight varieties at Karnal. But to give it the shape of scientific generalization of universal application, proving itself true under varying conditions, as he appeared to have done, is to ignore the basic fact that the host-pest complex consists of two living organisms which are influenced by changes in the environment in a variety of ways. That the characters of the host-plant contributing to the hardness of leaf midrib are not stable, has already been shown earlier in this section and that top borer is equally susceptible to such changes does not admit of any doubt.

As regards the question of inheritance of the hardness of leaf midrib, it might be stated that like all other characters, it is an inheritable character. But the precision with which its inheritance may be predicted is still very obscure. Even a progeny of both the parents having poor lignification may have high lignification in its midrib, as was the case with Co 331 (Co 213 ♀ × Co 214 ♂). Again examination of a few seedlings out of a cross which run into thousands, does not give any indication of its inheritability unless a major number of the seedlings studied for the purpose point in the same direction. In view of the complex heterozygous nature of the genetic make-up of sugarcane, next to nothing can be said as to whether this character is dominant.

The slow and laborious nature of the method adopted by Thuljaram Rao (*loc. cit.*) and its unsuitability for the purpose in view have already been pointed out elsewhere (Khanna and Sharma, 1947). It is not only tedious to draw each individual cell with its lumen, but also difficult to measure the latter accurately at magnifications below 1000 and the higher the magnification, the less the area covered by a microscope-field. It would, therefore, appear that the method does not meet the requirements of an investigation of this nature.

V. SUMMARY

1. The anatomical structure of leaf midrib of seven varieties, namely Co 213, Co 285, Co 299, Co 313, Co 331, Co 421 and Co 513 obtained from seven places from all over the country, was studied with a view to evaluating each anatomical feature, its stability in different environments and assessing the total hardness of the midrib by giving weightage to them on the basis of their role in imparting hardness and their stability. Also the behaviour of varieties as a whole at these places in two seasons was assessed.

2. Observations were made in detail on the following four features which together constituted all the strengthening structure of a midrib:

- (a) The area of vascular bundles.
- (b) The area of sclerenchymatous cushions.
- (c) The thickness of sclerenchymatous cell walls.
- (d) The thickness of outer wall of the long cells of the lower epidermis.

3. (a) It was found that the vascular area index was the most stable of all the four characters and the thickness of cell walls of both the tissues the least.

(b) Of the differences found to exist within these features, those due to varieties were the most pronounced in the thickness of cell walls and the least, in the case of the vascular area index.

4. (a) As regards varieties, Co 421 was distinctly different from the other two, namely, Co 213 and Co 313 which were similar to each other.

(b) Co 421 was most affected by variations due to places and by those due to changes within the same season. Change in the environment induced from season to season at the same place influenced Co 213 and Co 421 respectively to the greatest and the least degree. Co 313 was on the whole the most stable of all the three varieties.

5. (a) The varietal resistance to top borer was not found to be consistently the same at different places nor at the same place in different seasons. For instance, Co 421 was more susceptible than Co 313 at Pusa while the reverse was the case at Karnal.

(b) The correlation coefficient between the total hardness and top borer infestation was found to be -0.2685 , which was negligible and non-significant for the 26 pairs of observations.

6. The constituent factors going into the pest-host complex were of such varied nature that the resultant was not likely to be explained even on theoretical considerations by one single factor, namely the hardness of leaf midrib, which in the ultimate analysis was found to be a function of four highly variable anatomical features. On the basis of the investigations described in this paper it might be stated that hardness of leaf midrib by itself was not found to account for the differences in the varietal resistance to the top-borer attack in sugarcane.

7. A reference to Thuljaram Rao's work has been made while discussing the problem. His conclusions are based on too limited data and are likely to hold good only under a very limited set of conditions.

VI. ACKNOWLEDGMENTS

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EXPLANATION OF PLATES

PLATE I

T.S. of midribs of seven sugarcane varieties collected at Pusa in September 1942. Fig. 1, Co 213; Fig. 2, Co 285; Fig. 3, Co 299; Fig. 4, Co 313; Fig. 5, Co 331; Fig. 6, Co 421; Fig. 7, Co 513. The differences in their size are too obvious to need any mention. Vascular bundles though small in size are closer to one another in Co 285 than in Co 421 in which they are comparatively large. They are more spaced apart in the lateral sectors than in the median one of the section. Differences in the lignification of tissues, however, are not apparent in this magnification ($\times 10$).

PLATE II

T.S. of midribs of three sugarcane varieties collected in June 1942, at three places. Figs. 1-3, Co 213; Figs. 4-6, Co 313 and Figs. 7-9, Co 421: Midribs (Figs. 1, 4 and 7) at Pusa; Figs. 2, 5 and 8 at Shahjahanpur and Figs. 3, 6 and 9 at Karnal. Midribs of Co 313 and Co 421 are strongly arched earlier in season and become flatter later on (cf. Plate I, Figs. 4 and 5), while in Co 213 the degree of flatness is the same throughout the season. T.S. of the midribs of Co 213 and Co 313 collected at Karnal occupy greater area than those collected at Shahjahanpur and Pusa. In the case of Co 421, there is no such marked difference ($\times 10$).

PLATE III

Lateral (Figs. 1, 2, 3) and median (Figs. 4, 5, 6) sectors of T.S. of midribs collected at Pusa in September, 1942. Figs. 1 and 4, Co 213; Figs. 2 and 5, Co 313; Figs. 3 and 6, Co 421. The distance between vascular bundles in the lateral sector is appreciably greater than that in the median. It progressively decreases, especially in Co 213 and Co 421, as one approaches the axis of symmetry of the midrib ($\times 70$).

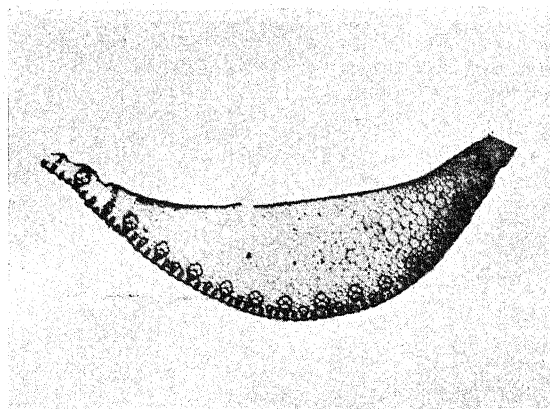


FIG. 1

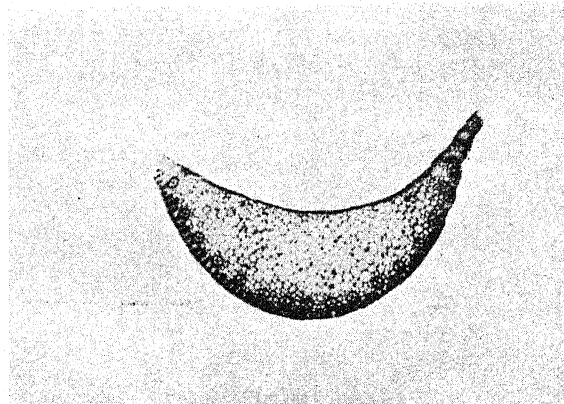


FIG. 2

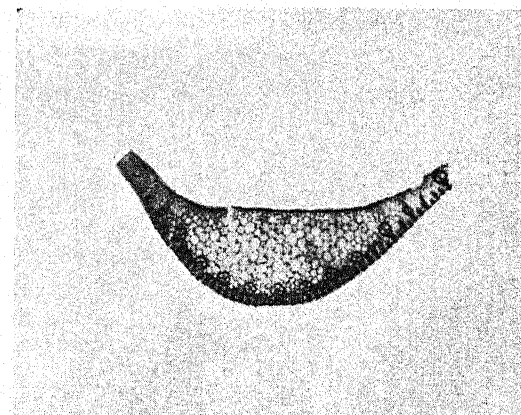


FIG. 3

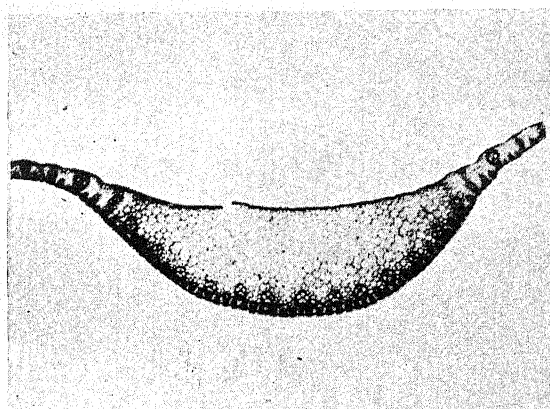


FIG. 4

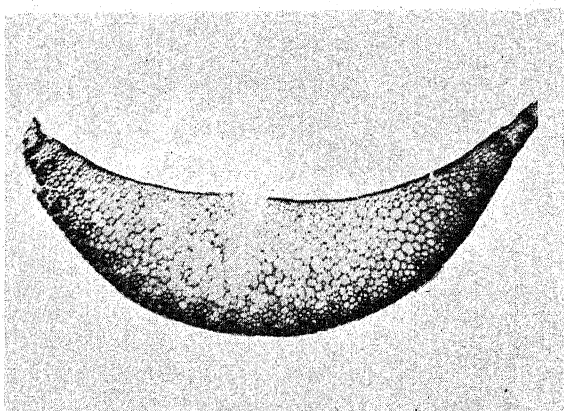


FIG. 5

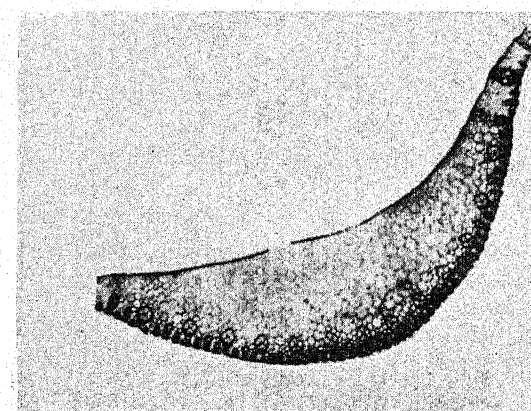


FIG. 6

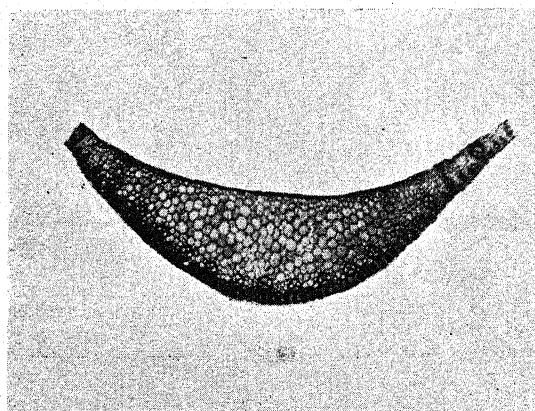


FIG. 7

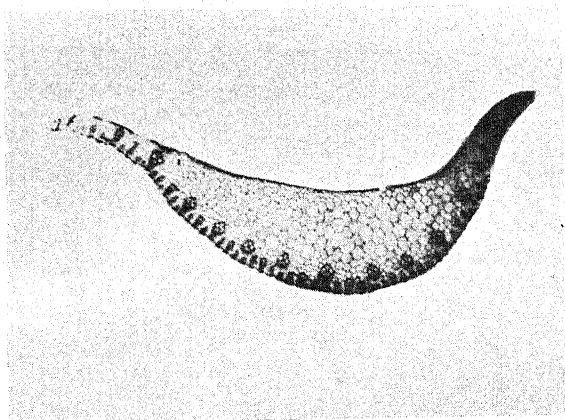


FIG. 1

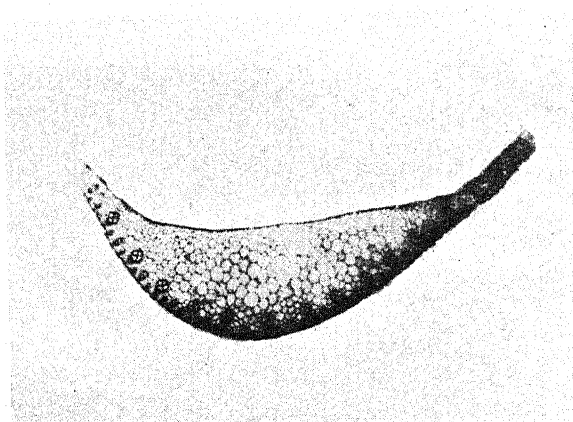


FIG. 2

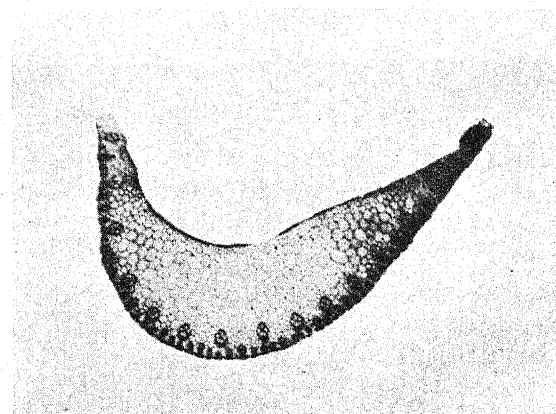


FIG. 3

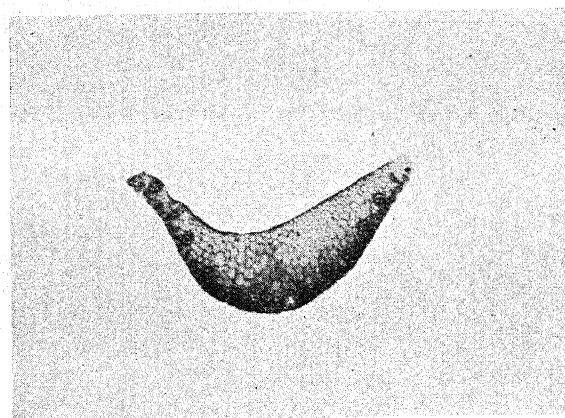


FIG. 4

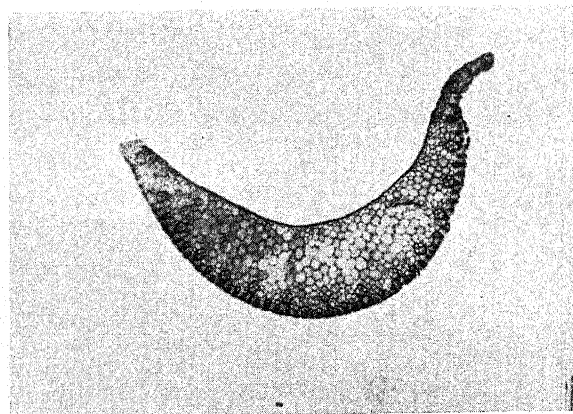


FIG. 5

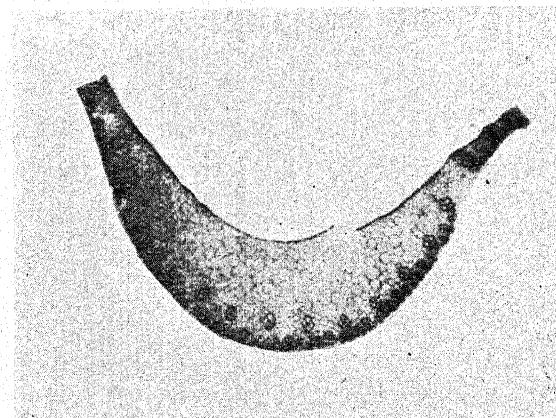


FIG. 6

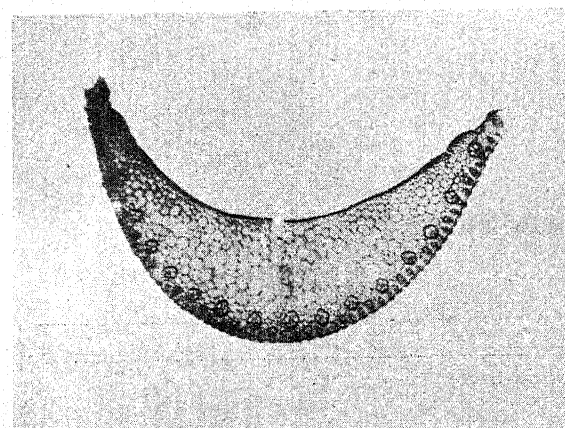


FIG. 7

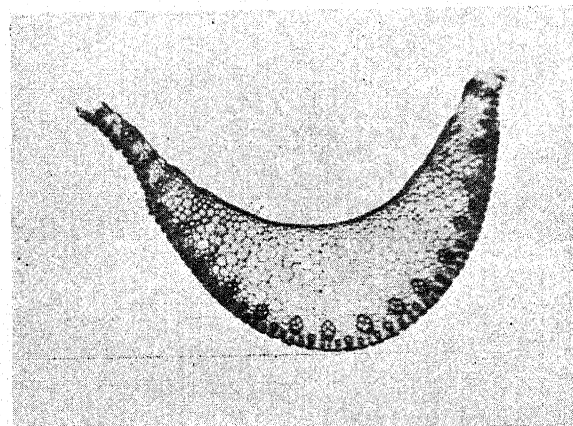


FIG. 8

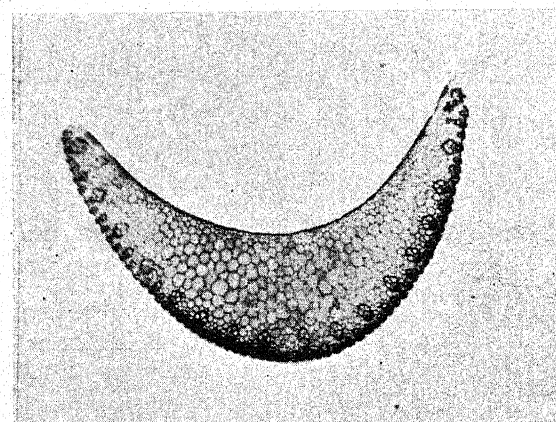


FIG. 9

FIG. 1

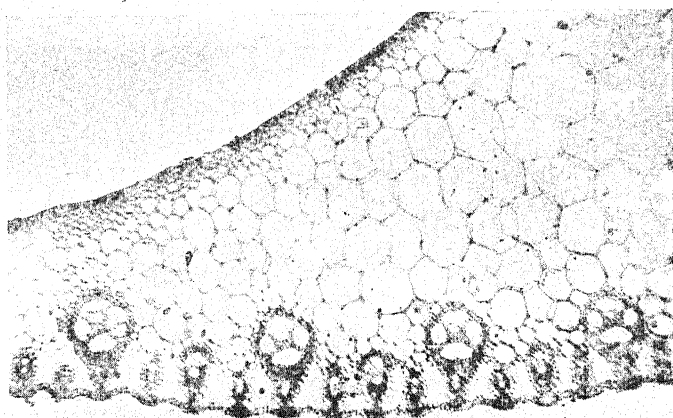


FIG. 4

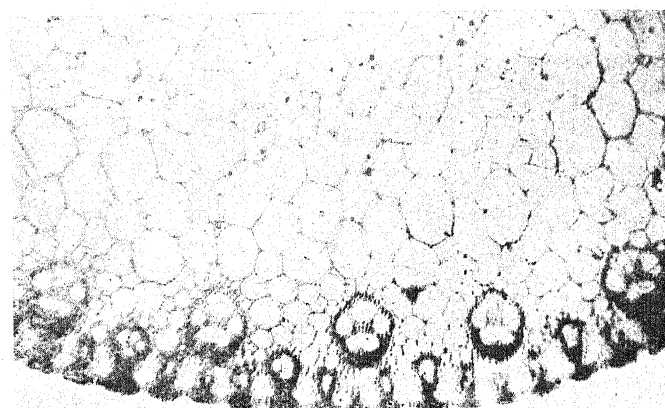


FIG. 2

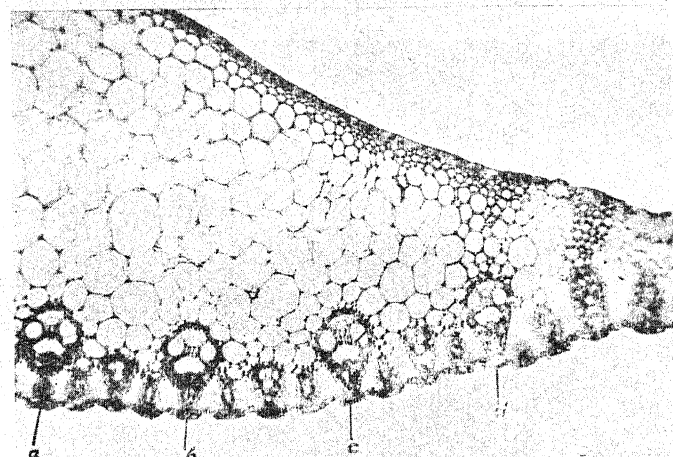


FIG. 5

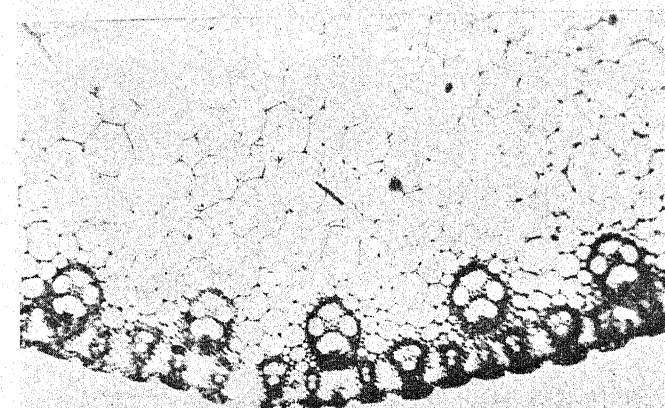


FIG. 3

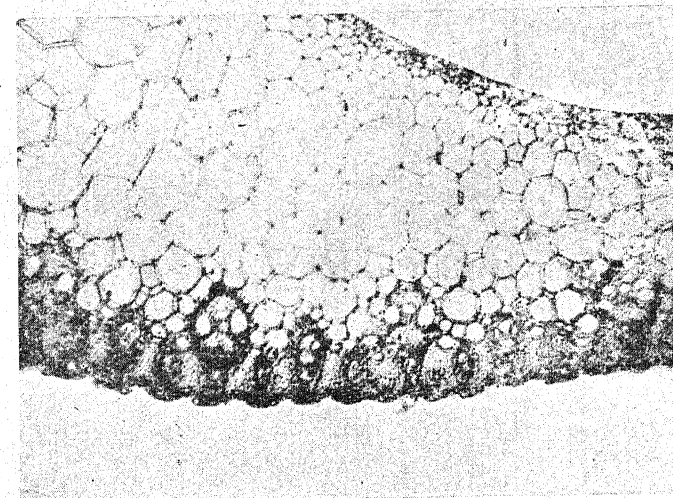
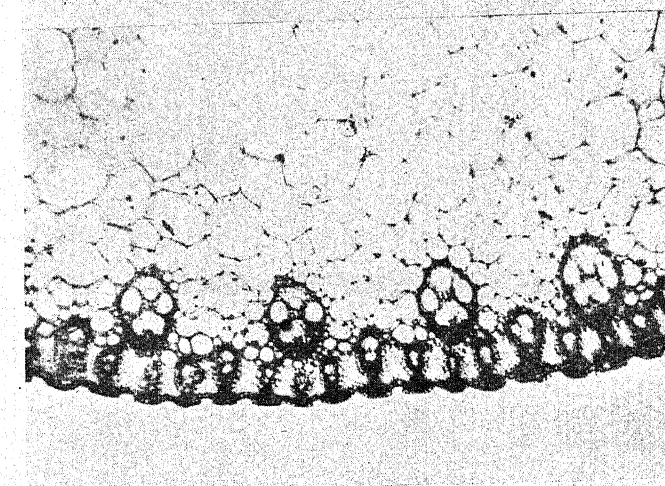


FIG. 6



THE PARASITE COMPLEX OF THE CASTOR SEMILOOPER, *ACHAEA JANATA* (LINN.)

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INTRODUCTION

The paper deals with the parasite complex of the semilooper, *Achaea janata* (Linn.), one of the important pests of castor. Mention is made of an egg parasite and several larval parasites including some hyperparasites. The egg parasite, *Trichogramma* sp., is recorded for the first time.

THE CASTOR SEMILOOPER

A brief account of the life-history and habits of *A. janata* is given here so as to indicate clearly the relationship between the host and the parasites. Out of the characteristic, green coloured eggs, generally laid singly on the upper surface of castor leaves, tiny caterpillars hatch out and feed on the leaves. The newly hatched caterpillar is 5 mm. long and $\frac{1}{2}$ mm. broad, while the fully grown caterpillar is about 50 to 60 mm. long and 5 to 7 mm. broad. It moults 5 times before it pupates. It completes its life-cycle in 22 to 30 days, the egg, larval and pupal periods being 3, 9-15 and 10-12 days respectively. The maximum number of eggs laid by a female moth was 648. The pest has been noted to feed on rose, pomegranate, *Euphorbia hirta* and *Tridax procumbens* and to appear on the castor crop from August to December-January.

PARASITES

A short account of the various parasites and hyperparasites is given below:

(1) *Trichogramma* sp.—This egg parasite was noted for the first time in January 1941 at Tindivanam and later in August 1942 at Coimbatore. The female parasite mates soon after emergence and starts depositing its eggs from the day of emergence. The total life-cycle of the parasite is 7 to 10 days. Under laboratory conditions, when fed with sugar solution, the maximum longevity of the male as well as that of the female was 4 days.

From a study of the number of parasites which emerged from eggs of *A. janata* collected from the field, it was found that out of 132 parasites which emerged from 35 eggs the number of females was 98, the percentage being 74.4. The maximum number of parasites which emerged from a single egg was 7 and the minimum one, the average being 3.8. Under laboratory conditions, when an egg was exposed to a number of parasites the maximum number of parasites which emerged from an egg was 11.

Field observations on the incidence of parasitism at the Agricultural Research Station, Tindivanam, show that the parasite occurs in large numbers from September to February. The following table gives the percentage of parasitisation of host eggs in the field in different months:

Percentage of parasitisation of host eggs in the field in different months

Sl. No.	Eggs collected on	No. of eggs collected	No. of parasitised eggs	Percentage of parasitised eggs
1	8-9-1941	94	94	100
2	10-9-1941	85	82	96.9
3	11-9-1941	87	87	100
4	17-9-1941	270	273	100
5	22-9-1941	355	324	91.3
6	23-9-1941	137	119	86.9
7	13-10-1941	122	120	99.0
8	14-10-1941	163	161	98.8
9	15-10-1941	45	45	100
10	27-10-1941	60	60	100
11	28-10-1941	50	50	100
12	1-11-1941	62	62	100
13	19-11-1941	90	88	97.8
14	28-11-1941	50	50	100
15	5-1-1942	60	54	90
16	15-1-1942	20	20	100
17	17-2-1942	16	16	100

There are possibilities of this parasite being bred in large numbers and tried in the control of the castor semilooper.

(2) *Microplitis maculipennis* Schz.—This Braconid which has previously been recorded is an internal larval parasite and attacks the early stage larvae. The parasitised caterpillar may be seen carrying underneath its anal end a dirty brown parasitic cocoon. The parasitised caterpillar does not feed and dies ultimately. A single parasite emerges from each cocoon. Such parasitised caterpillars are seen generally at the end of the season in large numbers. Counts made at the Research Station, Tindivanam, have shown that out of 922 caterpillars collected 518 were found parasitised, the percentage being 56.2.

Lyle (1921) described this species under *M. cusirus* from specimens reared from *A. janata* from Bihar and Orissa. Ramakrishna Ayyar (1921) described this under *M. ophiuseae* on *A. janata* from Coimbatore in S. India. Wilkinson (1930) gives the synonymy.

This parasite does not seem to have been recorded from any other host till now.

Two hyperparasites observed were *Brachymeria* sp. and *Tetrastichus* sp. Dutt (1925) records the Ichneumonid *Edrisa pilicornis* Cam. as attacking *M. ophiuseae*. Beeson and Chatterjee (1935) also record it as a hyperparasite on *M. maculipennis*.

(3) *Rhogas percurrans* Lyle—This is another Braconid parasite attacking the castor semilooper caterpillar in its early stages. The attacked caterpillar becomes mummified and forms the cocoon for the parasite inside. Only one parasite is got from a single host. The parasite is seen in small numbers towards the end of the season in December. This has a hyperparasite, *Brachymeria* sp.

(4) *Tetrastichus ophiuse* Crawford.—This Chalcid was described by Crawford (1922) from specimens on *Achaea* from Bangalore, India.

(5) *Euplectrus leucostomus* Rohwer.—This small Eulophid is an external larval parasite and attacks half-grown larvae. The eggs are laid in clusters of varying numbers on the body of the host dorsally and are found glued to the integument. The parasitic grubs emerging from the eggs feed in clusters by sucking the host caterpillar. It is only when they become full fed that the grubs separate themselves and crawl to the underside of the host and arrange themselves along its length transversely. Each grub spins a thin, loose cocoon and pupates inside; the adult comes out in about a week. This parasite also appears late in the season and is found in its turn parasitised by *Tetrastichus* sp.

Rohwer (1921) described the species. Ferriere (1941) redescribed it from specimens from South India—Coimbatore—ex-larvae of *Achaea*, and according to him forms from Kuala Lumpur, Malaya, ex-larva of a Pyralid belong to this species.

(6) Among the Ichneumonid parasites, Ramakrishna (1927) records *Paniscus ocellaris*, *Henicospilus* sp. and *Zaminochorus orientalis* Vier. on larvae of *Achaea janata*, the former two from Coimbatore and the last from Mysore.

Ramakrishna and Margabandhu (1934) record *Microtovidea lessonata* Vier. and *Hymenobosmina* sp. among the larval parasites of *Achaea*.

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STUDIES ON STORED GRAIN PESTS IN THE PUNJAB—VIII.*
EFFECT OF CONSTANT LIGHT AND DARKNESS ON
THE DEVELOPMENT AND REPRODUCTION OF
AND AMOUNT OF FOOD CONSUMED BY
TROGODERMA GRANARIUM EVERTS.

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I. INTRODUCTION

The larvae and the adults of *Trogoderma granarium* Everts. (*khapra*) react negatively to artificial and natural light (Rahman and Sohi, 1939). The behaviour of this pest in nature also confirms this observation (Rahman, 1944). This finding tends to indicate that light in the natural environments of *T. granarium* may inhibit its activity. As this finding is important from the point of view of effective control of the *khapra*, it was decided to determine the part played by light in the development, reproduction and food consumption of *T. granarium*. The results of these investigations are embodied in this paper.

The studies incorporated herein were carried out in the Entomological Laboratories, Punjab Agricultural College and Research Institute, Lyallpur, and formed a part of a thesis submitted by the author in partial fulfilment of the Degree of Master of Science in Agriculture of the University of the Punjab. The writer is indebted to Mr. M. Afzal Husain, I.A.S. (Retd.), for suggesting the problem and to Dr. Khan A. Rahman, Entomologist, West Punjab, for making useful suggestions during the progress of this work.

II. MATERIAL AND METHOD

The apparatus used for studying the effect of constant light on the development, etc., of *khapra* consisted of a 200 watts electric lamp (Fig. 1 a) immersed in water in a glass trough (Fig. 1 b) to absorb the heat radiated by the bulb. The hot water

* I. "Observations on the reactions of Dermestid beetle, *Trogoderma khapra* Arr. to light," *Indian J. Ent.*, 1939, 1, 57-63.

II. "Insect pests of stored grains in the Punjab and their control," *Indian J. agric. Sci.*, 1942, 12, 564-87.

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IV. "Save stored grain from insects," *Indian Farming*, 1943, 4, 18-20.

V. "Fighting *khapra* in the Punjab," *Indian Farming*, 1944, 5, 272-75.

VI. "Biology of *Trogoderma granarium* Everts," *Indian J. agric. Sci.*, 1945, 15, 85-92.

VII. "Mercury as a preventive against stored grain pests," *Bull. ent. Res.*, 1946, 37, 131-41.

in the glass trough was continuously replaced by fresh water from the tap (Fig. 1 c). The inflow of water from the tap into the glass trough and the outflow of water from the glass trough through the glass siphon (Fig. 1 d) were so adjusted that a constant level of water was maintained in the glass trough. Each larva was placed in a small petri dish (Fig. 1 e) containing a grain of wheat cut

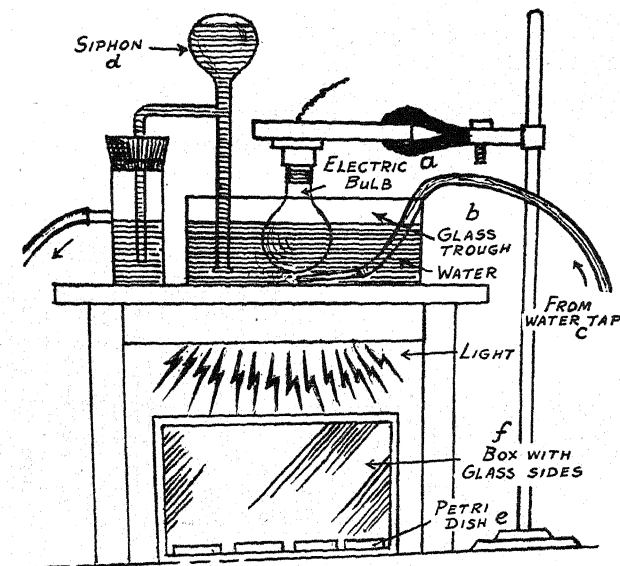


FIG. 1. Apparatus for studying the effect of constant light on *Trogoderma granaria* Everts.

longitudinally. The dishes containing the larvae were placed below the glass trough in a box with glass sides (Fig. 1f). The insects were thus exposed to constant light throughout the experimental period.

For studying the effect of constant darkness on the development, etc., the insects were bred similarly but in a black, double-walled wooden box ($1.5' \times 1.5' \times 1.5'$) having very narrow vertical slits in its outer and inner walls (Fig. 2). The slits (Fig. 2 a) were so arranged that they admitted free circulation of air without letting in light. This method also insured almost the same temperature inside this box (*i.e.*, under darkness) as under constant light.

Each larva was given a weighed quantity of grain with a view to determining its food consumption.

III. RESULTS

(a) *Development and reproduction.*—Light accelerated the development of the embryo as well as the growth of the larvae and the differences in the rate of their growth under light and darkness were found to be statistically significant (Table I); under constant light male and female larval stages respectively occupied, on an average, 19.1 and 23.36 days against 23.27 and 27.5 days in darkness. The relatively shorter duration of the larval stage under constant light had,

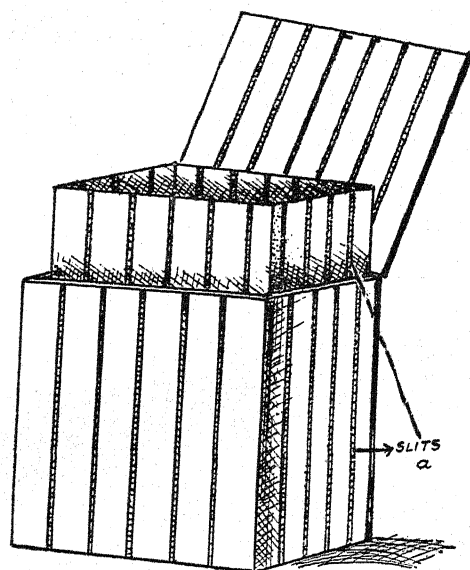


FIG. 2. Apparatus for studying the effect of constant darkness on *Trogoderma granaria* Everts.

however, an adverse effect on the egg-laying capacity of the females emerging from such larvae; on an average, a single female laid* 22.4 and 40.8 eggs under constant light and darkness, respectively (Table I). Moreover, such a female completed its life-cycle in 32.3 days under constant light against 35.6 days in darkness (Table I).

TABLE I. Duration (in days) of various stages of *T. granarium* under darkness and light

	Darkness Aver.	Light Aver.	Differ- ence	S. E. of the difference	d.f.	t
Egg stage	4.5	4.2	0.30	0.043	25	6.250*
Larval stage: Male	23.27	19.1	4.17	0.644	10	6.475*
Female	27.5	23.36	4.14	0.610	13	6.787*
Pupal stage	4.84	4.75	0.09	0.057	23	1.579†
Preoviposition period	1.0	1.0	..	..	..	..
Oviposition period	4.4	2.8	..	..	..	..
No. of eggs laid	40.8	22.4	18.40	2.420	4	7.603*
Minimum	91.2	90.7				
Maximum	97.2	98.4				
Average	94.4	95.0				

* Significant at 1% level.

† Insignificant.

(b) Food consumed.—In constant light the larvae consumed comparatively less food, both daily and in the aggregate. On an average, the daily consumption

* Normally a *T. granarium* female lays 34 eggs in its life-time.

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of food under constant light was 0.33 mg. and 0.11 mg. against 0.37 mg. and 0.19 mg. under constant darkness in the case of female and male larvae respectively (Table II). The female larvae consumed more food than the male larvae. The differences in the consumption of food under constant light and darkness were found to be statistically significant.

TABLE II. *Total and daily consumption of food by khapra larvae*

		Average total consumption in gm.		Average daily consumption in mgm.	
		Female larvae	Male larvae	Female larvae	Male larvae
Light	..	0.0076	0.0021	0.329	0.11
Darkness	..	0.0096	0.0043	0.373	0.188
Difference	..			0.044	0.077
S. E. of the difference	..			0.088	0.029
d.f.	..			6	5
t	..			4.957†	2.714*

* Significant at 5% level.

† Significant at 1% level.

The higher power of reproduction combined with the greater quantity of food consumed under darkness indicates that dark conditions are more favourable for the multiplication of *T. granarium* and storage under such conditions would lead to heavy losses as is often the case in closed mud bins and dark stores.

Efforts were made to utilize these observations for the control of this pest and the following laboratory experiments were conducted. Two metallic cylinders, each containing 12 seers (24 lbs.) of wheat were taken. Into each of these cylinders, one thousand larvae of *T. granarium* were introduced to start infection. One of these cylinders was covered with a metallic lid so as to create dark conditions while the other was covered with a glass lid. A 200 watts. electric lamp was hung at a height of 4.5 feet over the latter cylinder to provide constant light over the surface of grain. The experiment was started on 17th August and concluded on 30th October. It was observed that the pest multiplied at a much reduced rate under constant light. The percentage of attack and the percentage of loss in weight under constant light being 8.1 and 0.9, respectively, as against 20.7 and 1.9 under constant darkness.

IV. DISCUSSION AND CONCLUSIONS

There is considerable difference of opinion in India regarding the use of ventilated and non-ventilated stores against stored grain pests in general. Cole (1906) maintained that "a non-ventilated atmosphere provides the most favourable condition for the life and reproduction of weevils". Fletcher (1923) observed that grain stored in mud bins and dark stores was often more heavily attacked than that in well ventilated stores and he ascribed the difference to the greater variation in temperature to which the grain was exposed in well-ventilated-

stores. But this does not appear to be the real cause since *T. granarium* has been observed multiplying normally under extreme variations of temperature, i.e., in a black painted iron bin kept outside in the open at Lyallpur. Presence of light in well-ventilated stores is, therefore, responsible for lower *khapra* infestation. The wheat trade of this country, on the other hand, is of the opinion that the loss as a result of insect attack is less in dark and dingy stores, but Rahman (1944) says that in one and the same store, the population as well as the incidence of *T. granarium* are always higher in the dark portions of a wheat heap than in the lighted ones. The results reported in this paper together with earlier observations of Fletcher (1923) and Rahman (1944) clearly indicate that darkness is much more favourable for the multiplication of *T. granarium* than light. It is, therefore, tentatively concluded that in places where *T. granarium* is a pest, the store should be well lighted instead of being dark and dingy like the ones which are used by merchants and traders at the present time and the grain should be stocked in open heaps.

V. SUMMARY

Light accelerates the development of all stages except the pupal stage but reduces oviposition; on an average, a female lays 22.4 eggs under constant light against 40.8 eggs under constant darkness. Moreover, the amount of food consumed by a larva per day as well as throughout its larval period is greater under constant darkness than under constant light. The female larvae consume more food than the male larvae. Laboratory data with regard to storage experiments under constant light and darkness are presented and it is suggested that for reducing losses by *khapra* the store should be well lighted and wheat should be stored in them in open heaps.

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A TECHNIQUE FOR LARGE-SCALE FUMIGATION OF INFESTED GRAINS

By P. V. GEORGE, Madras, and M. C. CHERIAN, Coimbatore

INTRODUCTION

Large stocks of wheat held by the Government of Madras in various godowns in Madras City during 1943 were found infested in varying degrees. We were deputed by the Government to carry out necessary fumigation. In view of the urgency of the work and the time which should have been needed to make the godowns suitable for *in situ* fumigations, it was decided to commence fumigations straight off employing tarpaulins. Tarpaulin fumigation of infested bags has shown that the results are neither uniform nor quite satisfactory. Moreover, to fumigate such large stocks employing tarpaulins would have taken a very long period and caused considerable damage to the grains. Studies were therefore made as to the best method of fumigating the infested bags in as short a time as possible. As a result of these studies a technique for large-scale fumigation was devised and a short account of the same is presented in this paper.

PESTS OF WHEAT

The pests of wheat encountered were (1) *Sitophilus oryzae* (Linn.), (2) *Calandra granaria* Linn., (3) *Rhizopertha dominica* (Fabr.), (4) *Tribolium castaneum* (Herbst.), (5) *Latheticus* sp., (6) *Silvanus surinamensis* Linn., (7) *Laemophloeus* sp. and (8) *Plodia interpunctella* Hb. The consignments of wheat consisting of 94,000 bags (8,228 tons) showed varying degrees of damage ranging from 1.32 to 30.2%. Of the different pests, *S. oryzae* and *R. dominica* were found chiefly responsible for damaging the grains. *C. granaria* was noted for the first time presumably imported with the stock. This did not however appear to thrive in Madras.

FUMIGATION TECHNIQUE

(a) *Fumigant used.*—The choice of the fumigant lay between carbon disulphide and cyanogas ('A' dust). Cyanogas was readily available at Madras and it was chosen. After a series of preliminary trials it was found that the pests were rather resistant to ordinary doses and that a heavier dose of 3 lbs. per 1,000 c.ft. with an exposure of 24 hours was necessary to ensure effective results. This concentration of cyanogas was therefore employed throughout the fumigations.

(b) *Making the godowns suitable for fumigation.*—In all the buildings where *in situ* fumigations were undertaken, first a suitably designed network of lead pipes was laid so as to obtain an even distribution of cyanogas within the space. To assist effective extraction of residual gas from the fumigated buildings, at

a safe height (20 ft.) above the level of highest adjoining buildings, chimneys of suitable dimensions were built up of broad metal pipes and joined to one or more motor-driven exhaust fans fitted up for the purpose. As none of the godowns was in any sense fit for ready use as an air-tight chamber, stop-leak devices were undertaken till no obvious leakage was possible.

(c) *Machinery employed for fumigation.*—It was found that the usual cyanogas foot-pumps could not serve the purpose of large-scale fumigations, requiring the pumping in of large quantities of the dust. Therefore it was decided in consultation with the Engineering Department to employ a compressed air machine and a cement gunniting machine in combination. Fig. 1 shows the

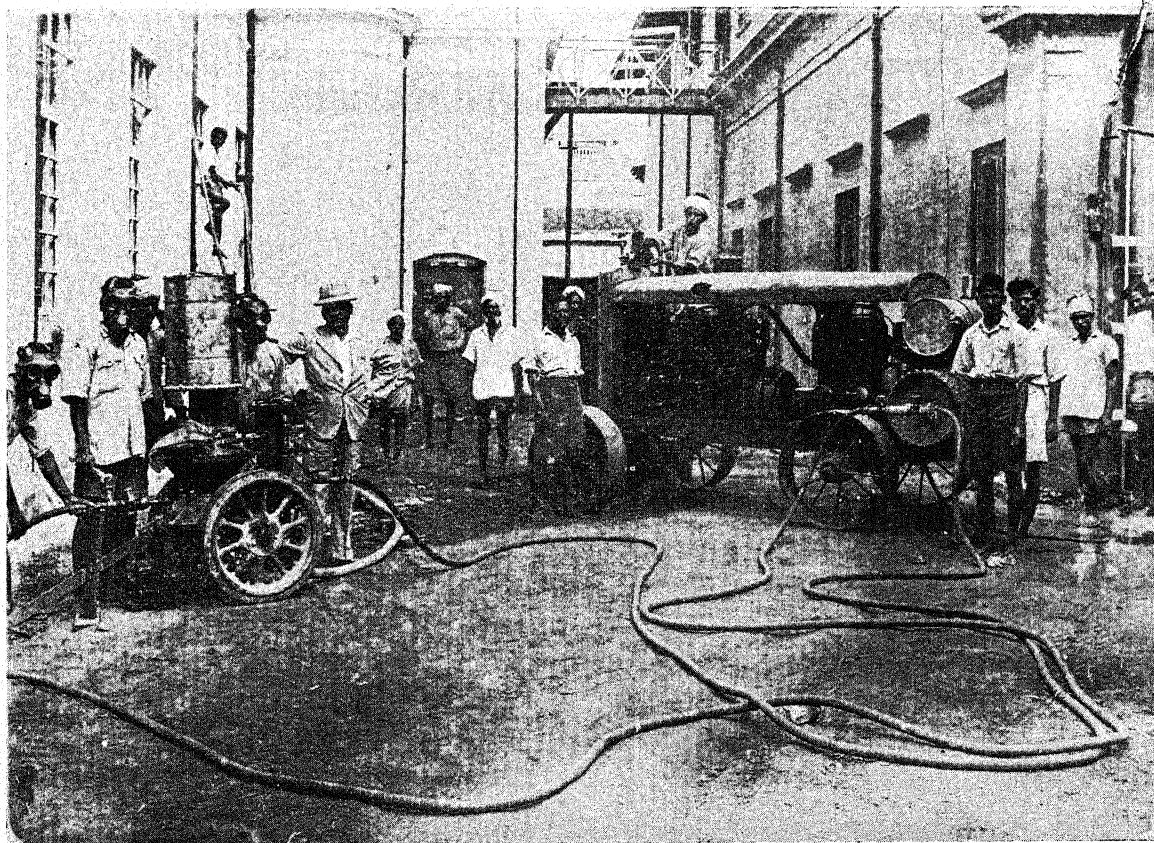


FIG. 1. A. Gunniting machine. B. Compressed air machine.

kerosene driven compressor machine and the gunniting machine in operation and Fig. 2 is a close-up view of the latter with the improvised attachment for holding a 100 lbs. cyanogas drum in position to feed the machine automatically and to avoid any handling of the poisonous dust. The attachment to the cyanogas drum was designed to discharge a regular and controlled flow of dust into the

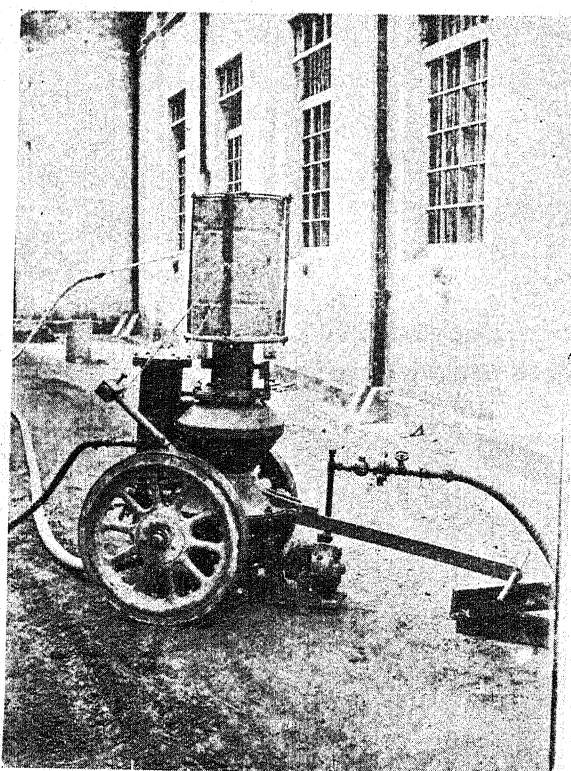


FIG. 2. A close-up view of the gunniting machine.

gunniting machine. This worked very effectively and gave a uniform forceful discharge of the dust into the chambers at 100 lbs. of the dust in about 10 to 15 minutes.

(d) *Details regarding in situ fumigations.*—Table I gives the details regarding the *in situ* fumigations carried out in the different godowns:

TABLE I

Godowns	Cubic space (c. ft.)	Quantity of cyanogas used in lbs.	No. of bags stocked at the time of fumigation	Time taken for gassing (in hours)	Time for degassing (in hours)	Date of fumigation
Stamp Office ..	98,892	300	8,706	4	17	28-5-43
Stationery ..	582,000	1,700	53,245	10	29	22 & 23-7-43
Harbour (top) ..	91,000	275	14,519	3	13	15-6-43
Harbour (bottom)	160,000	475	16,247	5	23	8-6-43

(e) *Special precautions taken to avoid risks.*—As the wheat stocks had been held in very busy and congested environments, it was found neither practicable

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nor economical to transport the stocks elsewhere to convenient places. Arrangements were therefore made to carry out the fumigations without in the least upsetting the normal business in the adjoining public offices or traffic along the roads, consistent with safety to the public and the personnel engaged. The wheat bags which had got wet during the rains were dried in the sun, rebagged and restocked. Fumigations were generally arranged in the afternoons after the public offices had been closed and in every case, previous written intimation was given to occupants of the time of fumigations with instruction to have the windows and doors on the windward side closed up during the gassing and degassing operations. A squad of Sanitary Inspectors and *maistries* detailed from the Madras Corporation was posted around the buildings to look for unexpected leakages, if any, and to give timely warnings to pedestrians, etc. A Corporation Ambulance van in charge of a medical officer with first aid equipment was always kept in readiness in the premises during the fumigations. A police squad was also stationed for day and night patrol around the buildings under fumigation. Pigeons and white mice in cages were employed at all stages to test any leakage of gas in lethal concentration. Chemical test papers sensitive to traces of hydrogen cyanide gas were also employed as indicators. The test solution consisted of benzidine acetate (saturated) and copper acetate (3%) freshly mixed in equal proportions. A change to blue either immediate or gradual was taken to indicate the extent of free HCN gas. These chemical and animal tests were specially helpful during the degassing operations.

Degassing operations were invariably done during the evenings after the neighbouring public offices had been closed, and the traffic was less busy. The buildings were opened up for natural aeration only after the chemical and animal tests were found negative. When aeration was deemed complete, samples of wheat, especially from bags in corners and pockets, were drawn in bottles, stoppered, labelled and sent to the Government Analyst for analysis for free or attached HCN in the grains. The aeration was invariably continued till the samples showed either nil or less than the permissible limit of HCN. After the certificate of clearance was obtained, coolies were engaged to clean off the dust from the bags and the floor of the rooms, for safe disposal. During these cleaning operations the coolies wore A.R.P. gas masks.

(f) *Testing the results of fumigation.*—The usual method is to take samples of grains after fumigation and sieve the material for noting the number of live and dead adults. This does not show whether the developmental stages inside the grains are affected or not. So the method recently advocated by Howe and Oxley for estimating insect infestation by estimating the CO_2 elaborated by insects in all their stages was used for assessing the results of fumigation. This method is, so far, not known to have been employed for this purpose and is described in a paper entitled "A new method for assessing the results of cyanide fumigation of infested food grains," published in *Chemistry and Industry*, 1944, 3: 24-25.

ACKNOWLEDGMENTS

The large-scale fumigation undertaken by us would have been difficult but for the ready help and co-operation of the several departments of Government. Special mention should be made of the help given by Shri K. Gopala Iyengar, Superintendent, P.W.D. Workshop, Madras. The subordinate staff who assisted in this work include Shri M. S. Kylasam, Assistant to the Government Entomologist, Shri R. N. Mariasusai Mudaliyar, Assistant Commercial Tax Officer and Shri B. Subramanian, Senior Stores Clerk.

A METHOD OF ASSESSING THE RESULTS OF CYANIDE FUMIGATION OF INFESTED FOOD GRAINS

By M. C. CHERIAN, Coimbatore, and P. V. GEORGE, Madras

INTRODUCTION

Food grains susceptible to ravages of insect pests require periodical disinfection to ensure safe and long storage. Correct methods of fumigation and tests for evaluating their efficiency have become all the more important in these momentous times when conservation of available food stuffs has become a vital problem for food administrators. Grains are known to be infested by a variety of pests, and these can be effectively dealt with by cyanide fumigation. The method so far used to observe the effect of fumigation has been to sieve samples and determine the percentage kill of adult insects. This method is obviously defective inasmuch as it does not provide for the inclusion of the larval stages of the same insects which are primarily concerned in damaging the grains and which cannot be recovered by any method of sieving. The method described below is one which can detect the existence of all stages of insect life by an estimation of the respired CO_2 in the samples before and after fumigation, giving due allowance for the CO_2 normally evolved by the grains themselves. This procedure was first described by Howe and Oxley (1944) for estimating the CO_2 figure for insect infested stored grains and was first utilised by us by its extensive application in several large-scale cyanide fumigations of Australian wheat in Madras. We have been able to confirm the great value of this most scientific method as an infallible test for all large-scale grain fumigations. These studies were carried out at the temporary fumigation laboratory, Madras, and the estimation of carbon dioxide was made in the laboratory of the Physiology Department of the Madras Medical College.

PESTS OF WHEAT STOCKS

The wheat stocks were found infested in varying degrees with *Rhizopertha dominica* (Fabr.), *Sitophilus oryzae* (Linn.), *Calandra granaria* Linn., *Tribolium castaneum* (Herbst.), *Latheticus* sp., *Silvanus surinamensis* Linn., *Laemophlacus* sp. beetles and *Plodia* caterpillars. Damage to grains was most severe and pronounced where the first two pests occurred in predominant numbers. *C. granaria* appears to be a new record for the Madras Presidency.

MATERIAL AND METHODS

Apparatus.—The following apparatus was used in the course of these studies:

(1) *Container for wheat samples for incubation.*—Bottles with tight fitting rubber corks were used. The corks were fitted with glass tubes of $\frac{1}{8}$ " calibre and of 6 inches length. One end of the tube was introduced into the bottle with grains and the other end was fixed with a short bit of rubber tubing with cork.

(2) *Sampling tube*.—This was used for withdrawing gas samples from the bottle containing wheat. Gas was withdrawn by replacement of mercury in the sampling tube.

(3) *Haldane gas analysis apparatus*.—The estimation of CO_2 was done employing Haldane gas analysis apparatus.

(4) *Sieves*.—Grain samples before and after fumigation were sieved in sieves made to retain the grains and to drop the insects.

(5) *Linen bags*.—The wheat samples after CO_2 analysis were emptied into linen bags for noting further emergences of adult insects, if any.

(6) *Desiccator*.—This was used in the estimation of the moisture content of the grains.

PROCEDURE

Bottles were dried before use and filled with grains. By tapping a few times, the bottles were filled to the top with grains. The cork with the capillary tube was then pushed down. The bottles were incubated at room temperature varying from 85° to 89° F., as facilities were not available to maintain a standard and constant temperature as recommended by Howe and Oxley. The period of incubation was near about 24 hours; where there was slight variation necessary corrections were made. Samples of air were drawn into the sampling tubes by replacement of mercury, and about 20 c.c. transferred to the Haldane apparatus. After adjusting the air sample to N.T.P., the CO_2 was estimated by absorption with potassium hydroxide solution. After the examination of CO_2 the wheat samples were sieved to note the number of insects, live and dead. The number of attacked grains was also noted. The grains cleared of all adult insects, live or dead, were refilled in linen bags and kept for weekly examination to note further emergence, if any, for developmental stages. A few samples of sound grains were also incubated and the CO_2 naturally elaborated by the grains determined. The respiratory CO_2 of the adults of *S. oryzae*, *R. dominica* and *T. castaneum* was separately estimated by introducing 100 adult live specimens of each of the species in the samples of sound grains. The moisture content of the different stocks of wheat used for the experiments varied from 7 to 9%. The average temperature during the period of the experiments ranged from 85° to 90° F.

ANALYSIS OF RESULTS

The statements given below summarise the results of CO_2 figures obtained for the different samples corrected for 24 hours of incubation. The grain samples incubated averaged one pound. Table I below compares the CO_2 figures of infested wheat samples before and after fumigation.

It was seen that fumigation with cyanogas in a concentration of 3 lbs. per 1,000 c.ft. for 24 hours was able to effect almost total destruction of the pests concerned. This was checked up by weekly examination of the samples kept in linen bags for about a month.

TABLE I. CO_2 figures of infested wheat samples before and after fumigation

Sample No.	Date of sampling	CO ₂ percentage	
		Before fumigation	After fumigation
1	28--7--1943	15.67	..
	30--7--1943	..	0.48
2	28--7--1943	12.94	..
	30--7--1943	..	0.12
3	16--7--1943	7.63	..
	2--8--1943	..	0.09
4	16--7--1943	5.50	..
	2--8--1943	..	0.09
5	16--7--1943	1.90	..
	2--8--1943	..	1.17
6	16--7--1943	1.12	..
	30--7--1943	..	0.06

CO_2 index of sound grains.--The sound grains were picked up from various consignments of wheat by examination of individual grains. The CO_2 figures obtained are in general agreement with those of Howe and Oxley except in sample number one (Table II) where possibly a few developmental stages concealed in the grains must have been overlooked in selecting the grains.

TABLE II. CO_2 figures for sound grains

Sample No.	Date of sampling	CO ₂ %
1	21--7--1943	0.55
2	4--8--1943	0.10
3	6--8--1943	0.09
4	6--8--1943	0.21
5	6--8--1943	0.24
6	6--8--1943	0.14

CO₂ RESPIRED BY INSECTS

An attempt was made to estimate the CO_2 respired by adults of *S. oryzae*, *R. dominica* and *T. castaneum* by artificially infesting known weights of sound grains (one lb.) with 100 adults of each of these species. The CO_2 figures after 24 hours of incubation were as in Table III.

It will be seen that both *Sitophilus* and *Tribolium* adults elaborate CO_2 almost to the same extent. In this respect the results obtained are at variance with those of Howe and Oxley. In the case of *Rhizopertha*, the CO_2 figure is only $\frac{1}{4}$ th of that of *Sitophilus* or *Tribolium*. Here it may be noted that only 36 *Rhizopertha* adults were found alive after the incubation whereas in the case of *Sitophilus* and *Tribolium* this number was 91 and 96 respectively.

TABLE III. CO_2 figures of adult insects

Sample No.	Date of sampling	Species and No. of insect	CO_2 % of grain and insects	CO_2 % of grains alone	CO_2 % of insects alone	Live insects after incubation
19	4-8-1943	<i>S. oryzae</i> 100	3.9	0.24	3.66	91
20	4-8-1943	<i>R. dominica</i> 100	0.97	0.14	0.83	36
21	4-8-1943	<i>T. castaneum</i> 100	3.81	0.21	3.60	98

INHIBITORY EFFECT OF CO_2 ON INSECT PESTS OF WHEAT

During the course of estimation of CO_2 of infested wheat samples it was found that under the effect of high concentration of CO_2 (over 10%) in the interstitial air the adults of these beetles could not survive. This was particularly so in the case of *Rhizopertha*. CO_2 had, however, no effect on the developmental stages of the insects.

In conclusion it may be stated that the method described above can be improved upon further, if mercury is avoided for aspirations in the sampling tubes by replacing it with an all-glass syringe lubricated with heavy medicinal paraffin oil where Haldane apparatus is not readily available or where it is considered somewhat cumbersome, a simple gasometric apparatus described by Oxley in *Chemistry and Industry*, 1944, No. 3, pp. 24-25, may be used.

ACKNOWLEDGMENTS

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THE BIOLOGY OF THE HAIRY CATERPILLAR (*EUPROCTIS SIGNATA* BLANCHARD) IN BALUCHISTAN

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I. INTRODUCTION

Euproctis signata Blan. (Lymantriidae, Lepidoptera) is fairly common in Baluchistan and in recent years the extent of damage by its larvae to fruit trees has increased so enormously that it has become a pest of first-rate importance. In view of its importance, the writer has made a detailed study of the biology of the pest during the last few years and the results are presented in this paper.

The writer feels indebted to Ch. Ghulamullah Khan, Assistant Entomologist, Quetta, for his valuable help during the progress of the work and to the Imperial Entomologist, New Delhi, for the identification of the species.

II. DISTRIBUTION

Euproctis is a widely distributed genus having its range over the Palaearctic, African, Oriental and Australian regions. In India and Pakistan, it is represented by about 52 species, some of which are serious pests of fruit, shade and forest trees and other plants, the larvae feeding gregariously and destroying the leaves. *Euproctis lunata* Wlk. is said to feed on *babul* (*Acacia arabica*), *ber* (*Zizyphus jujuba*) and rose. *Euproctis scintillans* Wlk. feeds on linseed, *bhindi* (*Hibiscus esculentus*), *bajra* (*Pennisetum typhoideum*) and probably other plants, and is recorded as damaging mango trees in Poona and *Terminalia catappa* in Calcutta. *Euproctis icilia* Stoll. feeds on the common *Loranthus* on trees and *Euproctis flava* Fab. (*guttata* Wlk.) on fruit trees of all kinds in the Punjab, the caterpillars of this species sometimes occurring in great abundance (Lefroy, 1909). *Euproctis fraterna* Moore is a serious pest of pulses, castor and rose, etc., in South India (Ramakrishna Ayyar, 1940) and of peach, plum, pear, apple, quince, apricot, pomegranate, rose, mulberry, *ber*, brinjal, etc., in the North-West Frontier Province (Pruthi and Batra, 1938). *Euproctis signata* Blan. occurs in Kashmir and the north-west Himalayas where it is responsible for wholesale defoliation of *Aesculus indica*, *Acer* spp., *Juglans regia*, *Parrotia Jacquemontiana*, *Pyrus* spp. and *Salix* spp. (Beeson, 1941). It has also been recorded from Muree, Punjab Hills (Strand, 1928). In Baluchistan it is being recorded for the first time by the present writer and is particularly abundant in the Quetta-Pishin district.

III. FOOD PLANTS AND NATURE OF DAMAGE

In Baluchistan, *Euproctis signata* Blan. is a very serious pest of apples, all varieties of which are almost equally attacked. Other fruit trees like pear, peach,

plum and apricot, growing near apple trees in the infested orchards, are also attacked but the larvae always prefer apples.

On apple, the larvae cause injury to buds, flowers, foliage and fruit. By about the middle of March, when the buds begin to swell, the tiny overwintering larvae become active and crawl out of their winter nests in which they live gregariously and scatter themselves on the tree, returning to their places of hibernation during night and the cooler parts of the day. They first attack the opening flower buds where they feed on the developing flowers, thereby lessening the setting of fruit. It has invariably been noticed that the larvae instead of completely destroying the flower bud, eat a portion of it and then move to the adjoining ones to repeat the same process with the result that the attacked buds are weakened to a very great extent and very few flowers develop. They also attack the blossom clusters and spoil them by feeding inside and webbing them together, thereby reducing the setting of fruit. Soon after the fruit has set and the leaves have developed, the larvae move to the foliage and settle on the leaves. If the leaf is young and not very hard, the entire leaf is eaten, excepting the petiole. In older leaves, however, a few of the bigger veins are left uneaten. The larvae at this stage are voracious feeders and in some instances the entire foliage and blossoms of trees in certain orchards are known to have been destroyed by these caterpillars. The newly-hatched larvae in June-July, however, feed on the soft parts of the leaves, leaving a network of veins and as a result of their feeding gregariously, invariably a major portion of the foliage of the tree is skeletonized. Sometimes the skin of the fruit is also nibbled and scratched by the larvae. Although these injuries are only skin deep, the fruit is invariably exposed to the attack of fungi and scavenger beetles from which a healthy fruit is usually immune. Rot sets in as a result thereof and the fruit is spoiled. The hairs covering the bodies of the larvae, larval moults, pupal cases, egg clusters and those of the anal end of the female moth are poisonous and cause irritation and blisters on the human skin on contact. Thus the carrying out of control and cultural operations and the picking of the fruit in the orchards become irksome jobs and sometimes when the larvae are present in large numbers, it becomes very difficult for the labourers even to enter the orchard.

IV. DESCRIPTION OF VARIOUS STAGES IN LIFE-HISTORY

The Egg.—The eggs are laid in flat, irregular, golden yellow clusters on the upper side of leaves usually near the midrib or over one of the larger veins. Each egg-mass is covered over by a felt of brown hairs deposited by the female from its anal tuft. They are glued to the surface by a sticky substance which soon hardens. In each cluster the eggs are closely packed spheres which may be laid in several layers. The average size of an egg cluster is about 2.8 mm. \times 8 mm. but there is a great variation in size and shape owing to the variable number of eggs comprising each mass. The average number of eggs per mass is about 437 but varies from 200 to 623.

The egg is round and creamy white. The length is 1.7 to 1.9 mm. The surface is smooth and has no superficial markings. A few days before hatching the eggs change in colour and become somewhat darker due to the colour of the developing larva inside. The larva finally emerges by cutting a hole in the top of its shell. The behaviour of the larvae at the time of hatching is very interesting. In one mass of 339 eggs, ninety per cent. of the larvae emerged in ten minutes.

The Larva.—On emergence, the larvae cut holes through the cluster-coverings and start feeding on the green tissue of the leaf that carried the egg cluster. After the green matter is eaten away, the leaf is rolled up with silken threads and inside the nest thus formed, the larvae live gregariously, coming out for feeding during the hotter part of the day. In the mornings and at night the larvae rest in these nests. As they grow in size, they scatter on the leaves for feeding and make large webs on the main branches and limbs of the trees wherein they rest during the night and also moult at intervals. If disturbed when feeding, the larva makes a quick wriggling backward motion and raises its body hairs which, as already stated, are poisonous when touched by hand.

The number of instars and the moulting activities of the larvae were studied in detail and it was ascertained that there are six larval instars in the Quetta Valley and the description of the various instars is as follows:—

First instar.—Length when newly hatched 3.2 to 3.5 mm., head 0.5 mm. wide. Soon after hatching the larva is light brown with feeble grayish spots spread over the whole body. Head dark brown; mouth parts much brighter in colour. Thorax concolourous with the body, the prothorax being a shade darker. On each side of pronotal plate there is an anterior verruca. Paired protuberances on abdominal segments 1 and 2 with brownish plumose setae. Sixth and seventh abdominal segments have each a pinkish raised papilla. The dorsal verrucae of nearly all the abdominal segments bear very fine white spicules forming tufts. The body skin bears several small setae, and a group of them on the 8th abdominal segment form a sort of tuft. Thoracic and prolegs brown having black bases and covered over by numerous setae. Each proleg bears nine or ten dark brown crochets in uniordinal series. Glands red. Spiracles indistinct.

Second instar.—Length soon after moulting 6.8 to 7.2 mm., head 1.3 mm. wide. Almost like first instar except that the general body colour is brownish with distinct grayish spots spread over the whole dorsal as well as ventral side. The colour of hairs on the body becomes golden. Each proleg bears fifteen to seventeen dark crochets in uniordinal series. Spiracles not very distinct.

Third instar.—Length soon after moulting 9 to 9.5 mm., head 2 mm. wide. The general colour of the body is of a deeper tone than in the second instar. There is a faint black dorso-lateral band along each side, which at the spiracular level is somewhat yellow. Hairs more abundant. Each proleg bears eighteen to twenty crochets in uniordinal series. Spiracles somewhat distinct.

Hibernation takes place in this instar.

Fourth instar.—Length soon after moulting 15 to 15.7 mm., head 3.5 mm. wide. The general body colour is much brighter and more strongly contrasted than in the previous instars. The hairs on the body are longer and more abundant, their colour now becoming darker. The grayish black patches on the body are more distinct. Each proleg bears twenty-two to twenty-nine crochets in uniordinal series. Spiracles distinct.

Fifth instar.—Length soon after moulting 20 to 20.9 mm., head 4.8 mm. wide. General body colour a shade darker than in previous instar. Head capsule of the same colour as in the fourth instar, adfrontal sutures now being distinct. The pink glands on the body segments are red in colour. Each proleg bears thirty-four to thirty-nine crochets in biordinal series. Spiracles circular with dark rims.

Sixth instar (Full grown larva).—Length soon after moulting 24 to 26 mm. but when full grown about 30 mm., head 5.4 mm. wide. General body colour brownish with black specklings on dorsal side, red variegation dorso-laterally and more reddish ventrally. Head and mouth parts dark brown with blackish specklings. Thorax blackish, the prothorax being a shade darker and bears a variably distinct pronotal plate, each side of which bears a large anterior verruca near the dorso-median line. Abdomen with black dorso-median line except on 6th and 7th abdominal segments. There is a black dorso-lateral band along each side; at spiracular level there is a considerable amount of brown. Paired protuberances on abdominal segments 1 and 2 with brownish plumose setae. Sixth and seventh abdominal segments have each a pinkish raised papilla. Verruca I not distinct; there are frequently scattered (secondary) setae mid-dorsally. Verrucae II and III of abdomen large, usually with a velvety surface; the paired verrucae II on abdominal segments 1 and 2 enlarged, verrucae III velvety brown; verrucae V and VI well developed. The dorsal verrucae of nearly all the abdominal segments bear very fine spicules; these spicules arise from very small patches of papillae, several spicules to a papilla. The spicules are minutely barbed and are trifid at the apex. The body skin bears several small setae not associated with verrucae; a group of golden brown setae on 8th abdominal segment which forms a sort of tuft. Thoracic and prolegs concolourous with the body having predominantly black bases and a number of setae spread over them. Glands red. Spiracles circular, distinct and with dark rims. Each proleg bears forty-nine to fifty-three crochets in biordinal series.

When the larva is about to pupate, it rolls a leaf with silken threads, spins a thin loosely spun cocoon inside which the larva pupates. Before pupating the larva excavates a short passage in the cocoon for the moth to come out.

The Pupa.—Length 11.7 to 12.2 mm., breadth 4 mm. across the wing covers on the third abdominal segment. Shape cylindrical, tapering posteriorly. General body colour light brown in the beginning, later on it becomes dark brown.

particularly on the dorsal side. Wing covers reaching the anterior ventral margin of the 5th abdominal segment. The intersegmental lines between the fourth, fifth, sixth and seventh segments of the abdomen form deep grooves around the body. Spiracles oval, raised, darker in colour than the general body. Abdominal segments devoid of any spines or setae. The maxillary palpi are about twice as long as the labial palpi and completely enclose the latter. The last segment ends in a flat tongue which bears 10 bristles which are incurved at the tip.

The empty pupal shell remains within the cocoon when the moth emerges out.

The Moth.—The moths are sluggish and because of their white colour, can be easily spotted out sitting on the leaves during daytime. If disturbed, they fly for a short distance. They are seldom attracted to lights or sugar baits.

Original description of the adult *Euproctis signata* Blanchard in *Ins. Voyage Inde Jacquimont*, IV, 1844, p. 24 is as follows:—

“Wings white, forewings marked with black. Apex of abdomen clothed with golden hairs.”

Strand (1928) describes the moth as follows:—

“Snow-white, forewing with a small black circle at the discocellular, and a small, black linear spot at the proximal angle. In some specimens only the latter is present. Anal brush golden-yellow.”

The following detailed description of the adult has been prepared by the present writer:—

“Head, thorax and abdomen black, apex of abdomen clothed with golden hairs. Palpi obliquely porrect, reaching beyond the frons; antennae bipectinate in both sexes, the branches long in male, each with a spine to keep it in position with regard to the contiguous branch. Mid-tibiae with one pair of long spurs, hind tibiae with two pairs. Female with a large anal tuft of golden yellow hairs. The forewings are entirely snowy white having a small black circle at the extremity of the discoidal cell and two black spots near each other on the posterior margin; in certain cases the latter only noticeable. Hindwings snowy white.”

Expansion: ♂ 30; ♀ 33–35 mm.

V. DURATION OF VARIOUS STAGES AND SEASONAL HISTORY

Observations made by the writer during the years 1942–45, show that there is only one generation of *Euproctis signata* Blan. in the Quetta Valley in a year. During the same period oviposition was observed to commence between June 5 and 14 and end between June 19 and 30. The incubation period varied from 29 to 40 days with an average of 33.6 days. Hatching commenced between July 7 and 19 and ended between July 20 and 31.

The larvae on hatching first feed on the leaf on which the egg mass is laid and later on go to the other leaves. During the cooler part of the day and at night they all return to the same leaf on which the eggs had been laid and lie in a sheltered nest made by the rolling of this leaf. The feeding period of the larvae before going into hibernation ranged from 82 to 89 days with an average of 84.6 days.

TABLE I. *Life-history data of*

Year	First eggs deposited on	Oviposition ended on	Incubation (days)		Hatching of eggs		Feeding period of larvae before going into hibernation (days)		Hibernation period (days)	
			Range	Mean	Commencement	End	Range	Average	Range	Average
1942 ..	8. VI	22. VI	29-36		10. VII	21. VII	83-86		1942-43	176-180
1943 ..	11. VI	25. VI	30-39	33.6	19. VII	24. VII	82-84	84.6	1943-44	179-184
1944 ..	5. VI	19. VI	32-40		7. VII	20. VII	85-89		1944-45	174-179
1945 ..	14. VI	30. VI	31-38		15. VII	31. VII	86-88		1945-46	182-189

On the onset of autumn, the larvae begin to desert the leaves and go into hibernation. The earliest date on which the larvae were found entering hibernation in 1942 was September 24, in 1943 it was September 30, in 1944 it was September 20, while in 1945 it was October 4.

The partially grown larvae pass the winter in hibernaculae made up of dry leaves rolled up together and securely tied up to the branches by means of silken threads. The whole hibernacula is also covered over by silken matting and becomes boat-shaped. When the trees are in dormant condition, these hibernaculae are quite conspicuous and are invariably found at the top of the shoots. It has been observed that 100-150 larvae live together in one hibernacula. Securely enclosed within the hibernaculae, the larvae pass the winter and with the approach of spring when the flower buds begin to swell and the development of the tender young foliage starts; they become active and crawl out of their winter hibernaculae and scatter themselves on the trees, returning to their winter hibernaculae during night and cooler parts of the day. In 1943, the first larva emerged on March 17 and the last on March 25; in 1944, the first larva came out on March 23 and the last on April 3; in 1945, emergence started on March 14 and continued up to March 24, while in 1946, the first larva emerged on March 27 and the last on April 9. The length of the time spent by the larvae in hibernation ranged from 174 to 189 days with an average of 178.7 days. During 1942-43, it was from 176 to 180 days, in 1943-44, from 179 to 184 days, in 1944-45, from 174 to 179 days while in 1945-46, it was from 182 to 189 days.

On emerging from the winter quarters, the larvae attack flower buds, young leaves, etc., in the manner already described. The feeding period of these overwintering larvae ranged from 34 to 55 days, with an average of 40.9 days.

At the end of the feeding period the larvae roll up leaves with silken threads and inside spin thin delicate silken cocoons to pupate. The prepupal period varied from 4 to 7 days with an average of 5.6 days. During the four years, the first pupation took place between May 5 and 14 and the last between May 13 and 23. The pupal period varied from 32 to 46 days with an average of 38.5 days.

Euproctis signata Blanchard (1942-45)

Feeding period of overwintering larvae (days)		Prepupal period (days)		Pupation		Pupal period (days)		Emergence of adults		Life-cycle (days)	
Range	Average	Range	Average	Commencement	End	Range	Average	Commencement	End	Range	Average
1943	38-54		4-6	6. IV	15. IV	33-45		6. VI	20. VI	343-387	
1944	34-52	40.9	5-7	5.6	9. IV	19. IV	36-46	38.5	9. VI	22. VI	346-392
1945	38-55		4-5		5. IV	13. IV	32-42		2. VI	15. VI	345-390
1946	36-53		5-6		14. IV	23. IV	35-44		11. VI	25. VI	355-398
											371.6

N. B.—Average based on 35 individuals.

In 1943, the first moths started emerging on June 6 and the last on June 20. The dates of the first emergence during the following three years were June 9, June 2 and June 11 and emergence continued up to June 22, June 15 and June 25 respectively. The length of life of the adult varied from 5 to 7 days, the average being 5.9 days during June 1945.

Copulation takes place soon after the adults emerge and lasts from an hour to an hour and a half. Invariably it takes place at night. The preoviposition period varied from 3 to 5 days with an average of 4.2 days.

The egg-laying activities of the moth were observed in detail. Oviposition usually occurs either early in the morning or just after sunset. As the time for oviposition approaches, there are indications of excitement on the part of the female. After some time she becomes quiet and selects a place on the upper surface of the leaf where she rests. She then lifts the tip of her abdomen and lays her eggs. As the eggs are being laid, she goes on covering them with the hairs of her anal tuft and dies at the end of the process. As a rule only one egg mass is laid by a female but if disturbed during the process, she may deposit 3 to 4 such masses. The average number of eggs deposited by a single female moth was 439.9—ten females depositing 4,399 eggs. The maximum number of eggs deposited by a single female was 627 and the minimum 298.

The life-history data for 1942-45 are summarized in Table I.

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BIOLOGY OF THE SUGARCANE ROOT-BORER, *EMMALOCERA* *DEPRESSELLA* (SWINHOO) IN THE PUNJAB

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I. INTRODUCTION

The genus *Emmalocera* is fairly widely distributed throughout the world and about a dozen of its species are of economic importance. *Emmalocera depressella* (Swinhoe) is the commonest species in India where it was first recorded from Dharmasala, Poona, Nilgiris and Pulo Laut (Hampson, 1896). Later, Dudgeon (1905) recorded its occurrence at Burogha and in Bengal. Mackenzie and Lefroy (1908) collected specimens of it from Bihar. Isaac (1934) found it in Karnal, Mushery and Delhi. According to Rahman and Singh (1942) it occurs in the Punjab, Delhi, U.P., Bengal, Bihar, Mysore and Bombay.

In the Punjab, a survey of the important sugarcane growing tracts showed *E. depressella* to be of very wide distribution, being present in fairly large numbers in Lyallpur, Montgomery and Shahpur where its attack in young shoots varied from 6.3 to 11.6%. In Rohtak, Karnal, Jullundur, Amritsar, Gujranwala and Sialkot it attacked 3.3 to 5.3% shoots during May and June, while at Ambala, Gurdaspur, Hoshiarpur, Gujrat, Jhelum and Rawalpindi where it was of minor importance, its attack during May-June varied from 0.8 to 2%.

II. SYNONYMY

The original name of the species under discussion was *Melissoblastes depressella*, described by Swinhoe in 1885. Hampson (1896) described it under *Polyocha depressella*. According to him, a synonym was created when Rag described *Polyocha variegatella*, but later on *Polyocha variegatella* was considered a valid species (Hampson, 1918). Dudgeon (1905) created another synonym by describing *Polyocha saccharella*. In 1917, *Polyocha depressella* was transferred to *Papua* and later on to *Emmalocera* (Hampson, 1918).

III. FOOD PLANTS

In the Punjab, *E. depressella* was observed to feed on the following plants besides sugarcane:—

- | | |
|--|--|
| 1. <i>Sarkanda</i> (<i>Saccharum sara</i>) .. | .. At Lyallpur, Bhalwal, Amritsar, Karnal, Ferozepur, Lahore and Sheikhpura. |
| 2. <i>Baru</i> (<i>Andropogon halepensis</i>) .. | .. At Amritsar, Bhalwal, Ferozepur and Karnal. |

3. Chari (*Andropogon sorghum*) .. At Lyallpur.
4. Napier grass (*Pennisetum purpureum*) .. At Lyallpur.

IV. LIFE-HISTORY

Not much work has so far been done on the life-history of *Emmalocera depressella* in India. According to the casual observations of a few workers, the duration of the life-history of this pest has been variously estimated, viz., one month (Ghosh, 1917), 56 days (Fletcher, 1919), 56-59 days (Isaac and Misra, 1933) and 63-73 days (Rahman and Singh, 1942).

Regular observations on the life-history of this pest were carried out at Lyallpur for fully two years from 1942 and the observations made are given below:—

Post-copulation period.—Since moths do not copulate in captivity, copulating pairs, whose time of emergence was not known, were collected from light traps in the sugarcane fields and liberated on shoots in earthen flower pots covered by glass chimneys. The date on which oviposition started was recorded, the post-copulation period being thus obtained. Such records were worked out for all the broods, which were found to be five in number. As it was very difficult to get a large number of copulating pairs at light traps, observations were confined only to a limited number of pairs, for all of which standard error was worked out. The results are summarised in Table I.

TABLE I. *Post-copulation period of E. depressella for the different broods*

Broods	Number of observations	Post-copulation period (in days) average (with S. E.)
I	5	3 constant
II	7	3 constant
III	7	3 constant
IV	7	3.5 ± .218
V	6	4.0 ± .368

Pre-oviposition period was, however, studied in the females which emerged in the laboratory and laid eggs parthenogenetically. These females started laying eggs on the 4th night after emergence and continued laying up to the 7th and 8th nights.

Oviposition.—In captivity eggs were either found to be laid singly or in clusters of 2-13. The eggs in the clusters were either laid side by side or overlapping each other. In the fields, however, eggs were always found laid singly. Husain (1928) has recorded 277-355 eggs to have been laid by a single female in its life-time. Oviposition in all the 5 broods was recorded from females collected from light traps. Summary of the results is given in Table II.

TABLE II. *Number of eggs laid by E. depressella during different broods*

Broods	Number of observations	No. of eggs laid by a female Average (with S. E.)
I	5	184 \pm 27.4
II	7	260 \pm 16.9
III	7	272.5 \pm 9.8
IV	7	261.4 \pm 28.6
V	6	215.6 \pm 17.4

Time of oviposition.—Eggs are always laid at night. In order to record the time of maximum oviposition, females were kept on shoots under glass chimneys during May-June, 1944, and again in May, 1945, one at each time. The results are presented in Table III.

TABLE III. *Oviposition of E. depressella during different hours*

Time	8-30-9 P.M.	9-10 P.M.	10-11 P.M.	11-12 P.M.	12-1 A.M.	1-2 A.M.	2-3 A.M.	3-4 A.M.	4-5 A.M.
No. of eggs laid during each hour by a single female in one night—									
May, 1944	7	21	36	19	6	3	..	2	..
June, 1944	..	4	17	29	23	11	3	4	..
May, 1945	..	2	23	27	18	4	5	2	..

It is seen from the above table that most of the eggs were laid from 9–12 P.M.

Oviposition in darkness and light.—The effect of light and darkness on the rate of oviposition was studied by confining six copulated females in separate chimneys. Three of them were kept in a dark room and the other three in a lighted room. Observations were recorded only from 9–12 P.M. as most of the eggs were laid during that period. The results are presented in Table IV.

TABLE IV. *Rate of oviposition of E. depressella under light and darkness*

Month	Time of observations	No. of observations	No. of eggs laid in	
			Darkness	Light
April, 1945 ..	9-12 P.M.	1	66	37
	do	1	56	47
	do	1	70	41

It is observed from the above table that comparatively larger numbers of eggs were laid in darkness.

Females which were previously kept in light were shifted to the dark room after 12 P.M. and their rate of oviposition was compared with that of those kept in darkness. It was observed that a female which was previously kept in light

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laid, on an average, 23 eggs between 12 P.M. to 4 A.M. as compared to 14 eggs laid by a female which was all along kept in darkness.

Place of Oviposition.—In the laboratory eggs were laid on soil, leaf, stem and on the inner surfaces of the glass chimney. It was observed that during May 1943, 67% of the eggs were laid on soil, 15.8% on the leaves, 11.2% on glass chimney and 6.2% on the stem. In the field, eggs were observed to have been laid on leaves, stem and soil; those laid on the soil were detected only when the soil was wet. During the early stages of the crop growth when shoots had put forth only 4 side leaves and a central spindle, most of the eggs were deposited on the first and the second leaf though a few eggs were also laid on the third and the fourth leaf and stem. Later when the plants had put forth more than 10 leaves, eggs were observed to have been deposited on the 6th to 10th leaf with the maximum number on the 8th. At this stage, out of 500 eggs examined in an area of 1/160 acre, 63% of eggs were laid on leaves, 3.5% on stem and 1.5% on the soil. The lowermost two leaves being generally smeared with mud and water had seldom any eggs on them.

Position of eggs on leaves.—The eggs are laid generally on the under surface of the leaves. Out of 500 eggs observed during May, 2.4 and 21.6% were laid on the leaf-blade and on the midrib of the upper surface of leaf, respectively, whereas 34.2 and 41.8% were laid on the leaf blade and along the midrib of the lower surface of the leaf, respectively.

Post-oviposition period.—The period between the laying of the last egg and the death of the female was recorded. Although generally the females died soon after laying the eggs, yet in certain cases they lived from 1–5 days after oviposition.

Incubation period.—Husain (1928) recorded that eggs hatched after 4 days when exposed to 93°–101° F., with 22–100% humidity. Isaac and Misra (1933) also observed that eggs took 4 days to hatch. Fletcher (1919) and Rahman and Singh (1942) recorded the incubation period to be of 3 and 3–5 days, respectively. In order to study the incubation period under natural conditions, sugarcane plants were selected at random in the field and leaves without eggs were marked. The leaves were examined daily in the morning and when any egg was found laid, that leaf was labelled and the date recorded. Daily examination of such eggs was continued till they hatched. Summary of the results is given in Table V.

TABLE V. *Incubation period of eggs of E. depressella*

Brood	No. of observations	Average period of incubation with S. E.
I	40	5.5 \pm 0.21
II	40	4.7 \pm 0.258
III	38	5.12 \pm 0.23
IV	39	5.77 \pm 0.33
V	40	8.6 \pm 1.11

Shrivelling of eggs during May.—Effect of hot and dry winds on the eggs laid on leaves of sugarcane in the fields during the month of May was recorded. Out of 1,000 eggs examined on the upper surface of leaves, 20·8% were found to have shrivelled up, whereas out of 500 eggs examined on the lower surface of the leaves only 9·4% were found to have shrivelled up. The temperature and humidity during that month varied from 65°–119° F. and 28 to 68% R.H., respectively. Temperature and humidity record of each month for the year 1944–45 is given in Appendix 'A'.

Hatching.—Hatching usually takes place in the morning hours (4–7 A.M.). The hatching larva cuts the chorion with its mandibles and escapes from the egg shell by wriggling movements.

Behaviour of freshly hatched caterpillar.—A freshly hatched caterpillar when liberated on a young sugarcane shoot normally crawled along the underside of the edge of the leaf and moved along the stem. It sometimes got obstructed by the hairs at the base of the leaf. It either got entangled in these hairs or crawled through along places devoid of hairs down to the base of the shoot through some crack often noticed in the stem. In some cases the caterpillar after reaching the stem creeps down the hollow space between the basal leaf sheath and the stem. A caterpillar thus took 6–11 minutes to crawl to the base from the leaves which were 9–11 inches above the ground level. Sometimes it descended to the soil by means of a silken thread whence it was carried away by ants if it did not succeed in locating a shoot.

Successful boring.—The caterpillars after hatching, thus lead an exposed life for a short while, at which time some of them are either attacked by predators or after dropping to the ground may fail to reach a plant. In order to find the percentage of caterpillars which succeeded in boring, numerous freshly hatched caterpillars were liberated on 15 young plants. During May, the percentage of caterpillars which successfully bored into the roots was 10%, while during August out of 150 freshly hatched caterpillars liberated on 15 different shoots, only 18·0% successfully bored the root stocks.

Larval period.—According to Fletcher (1919), the larval period of this pest occupied 41 days, while according to Rahman (1940) it occupied 45–50 days. In order to study the larval period a known number of freshly hatched caterpillars of each brood was liberated on shoots. As all the activities of the caterpillar are below ground, great difficulty was experienced in finding out the exact duration of the larval stage. The technique for studying the larval period was as follows:

A few of the plants on which the caterpillars had been liberated, were examined and those in which the caterpillars were full fed were inserted in the wet soil again and re-examined by digging them out daily. Thus the date of pupation was recorded and the larval period calculated, the summary of which is given in Table VI.

TABLE VI. *Duration of larval stage of E. depressella in different broods*

Brood	Number of observations	Average larval period (in days with S. E.)
I	10	29.7 \pm 1.101
II	7	32.85 \pm 1.28
III	9	36.3 \pm 1.06
IV	9	39.3 \pm 1.84
V	9	198.9 \pm 4.4

It will be observed from the above table that during 1st to 4th brood (April-October) the larval period, on an average, occupied 29.7 ± 1.101 to 39.3 ± 1.84 days while caterpillars of the 5th brood (October-March) required 198.9 ± 4.4 days to complete the larval stage.

Pupation.—During April-June the full-fed caterpillar of *E. depressella* comes up in the cane stem just above the level of the soil surface and, before pupation, cuts a circular hole on an average 0.8 inches above the ground in the rind, fastening the cut rind with silken threads to the circular hole. From the place where the circular hole is cut, it sometimes constructs a small tube of silk and frass, about 0.5" in length, which projects out from the stem at right angle. The caterpillar then pupates just at or below the surface level. During winter when canes are harvested, it has been observed making a tube of silk and frass leading almost to the surface of the soil. The caterpillar at that time pupates, on an average, 1.6 inches below ground level.

Pupal period.—According to Fletcher (1919), pupal period takes 12 days, while according to Rahman and Singh (1942) it occupies 15–18 days. In order to find out the pupal period in all the five broods, the root stocks containing full-fed caterpillars were planted in flower pots, and the dates of their pupation and emergence of adults were recorded.

TABLE VII. *Duration of the pupal stage of E. depressella in different broods*

Brood	Number of observations	Average pupal period (in days with S. E.)
I	10	11.5 \pm .299
II	10	10.3 \pm .63
III	10	12.8 \pm .36
IV	10	14.1 \pm .35
V	10	9.8 \pm .49

Emergence.—In order to find out the time of emergence of adults, 50 pupae were kept in a dish during April, 1944. The first adult emerged at about 7–20 P.M., 33 emerged from 8 to 9–30 P.M. and the rest emerged between 10–30 to 12 P.M.

Behaviour of freshly emerged adult.—The adult of *E. depressella* emerges after rupturing the head and dorsal thoracic region of pupal case. During May, the

moths were never seen on the green portion of leaves and stem but were generally found in a state of torpor on the basal dry leaves with wings pressed to the body and antennae thrown back.

Longevity.—The males of *E. depressella* are short lived. They live for 3–5 days during April–June and for 4–7 days during September–October without food. The females lived for 4–9 days during April–June and 6–12 days during September–October.

Progress of attack of root-borer from brood to brood.—In an area of about one and a half acres of sugarcane at Lyallpur Agricultural Farm, 500 shoots were examined during each brood and the percentage of caterpillars present each time was recorded. The caterpillars were again liberated on the root stocks to avoid disturbance in the population. This was done by removing earth and making a small hole in the root stock to facilitate entry, as it had been ascertained that the caterpillars, in all stages, could successfully bore. The results of these observations are given in Table VIII.

TABLE VIII. *Progress of attack of E. depressella from brood to brood*

Brood	Number of shoots examined	Number of caterpillars	Percentage
I	500	32	6.4
II	500	44	8.8
III	500	53	10.6
IV	500	65	13.0
V	500	97	19.4

It will be observed from the above table that an increase in infestation was not much marked in the first three broods but was appreciably noticeable in the 5th brood.

Seasonal History.—The pest starts emergence in the first week of April and passes through five broods in a year. In the first week of December the caterpillars of the 5th brood enter into hibernation in the stubbles of sugarcane. The overwintering caterpillars start pupation during the second fortnight of March.

V. ACKNOWLEDGMENTS

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VI. SUMMARY

Emmalocera depressella (Swinhoe) is fairly widely distributed in India, and in the Punjab it is mostly found in the drier parts, viz., Lyallpur, Montgomery and Sargodha where it destroys 11.6% of young cane shoots in certain years. Besides sugarcane it has been recorded on *Saccharum sara*, *Andropogon halepensis*, *Andropogon sorghum* and *Pennisetum purpureum*.

The pest is active from April to November and passes through five broods. The caterpillars of the fifth brood enter into hibernation in the stubbles of sugarcane plants. The over-wintered caterpillars pupate during the second fortnight of March and adults start emerging in the first week of April. Eggs are laid at night usually from 9-12 P.M., 3-4 days after copulation. A female, on an average, lays 184, 260, 272.5, 261.4 and 215.6 eggs during the I, II, III, IV and V broods respectively. Eggs are deposited mostly on sugarcane leaves, and rarely on stem and soil. During the earlier stages of plant growth, these are laid mostly on the underside of first and second leaf, along the midrib but in the later stages on the sixth to tenth leaf, the maximum number being laid on the eighth leaf. Egg, larval and pupal periods occupy 4.7-8, 29.7-109.8 and 9.7-14.1 days respectively during different broods. A freshly hatched caterpillar takes 6-11 minutes to crawl to the base of the shoot a distance of 9-11 inches. 10 and 18 per cent. of the caterpillars bore successfully in the roots during the months of May and August respectively. Pupation takes place just at or below the soil surface during the earlier stages of plant growth, when a full-fed caterpillar, before pupation, makes an exit hole 0.5" above ground level. During later stages of plant growth a full-fed caterpillar, before pupation, constructs a tube of silk and frass leading to the soil surface and pupates at an average depth of 1.6" below ground level. Emergence of moths takes place soon after dusk and the majority of them emerge between 8 P.M. and 10-30 P.M. Males live for 3-5 and 4-9 days and females for 4-7 and 6-12 days during April-June and September-October, respectively.

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APPENDIX A

Meteorological Data of Lyallpur (Punjab), 1944-1945

Month	Temperature in degrees Fahrenheit			Humidity			Rainfall in inches
	Maximum	Minimum	Average	Maximum	Minimum	Average	
April ..	104.0	54.1	78.4	94	30	60.3	2.68
May ..	119.0	65.0	93.0	68	28	39.0	0.22
June ..	116.5	71.1	83.2	75	21	47.9	0.68
July ..	113.0	76.1	92.2	98	41	74.4	3.47
August ..	101.2	73.3	86.7	95	73	83.6	6.85
September ..	100.2	64.9	80.7	95	55	74.0	1.55
October ..	99.0	53.1	76.4	88	45	69.3	..
November ..	90.2	43.7	66.8	93	62	84.4	..
December ..	82.0	32.5	54.6	100	73	70.3	..
January ..	74.0	30.1	51.8	100	64	87.2	1.75
February ..	79.8	36.1	62.1	91	46	72.8	0.03
March ..	95.8	36.9	67.7	95	37	75.0	1.20

BIOLOGY OF *CHRYSOPA SCELESTES* BANKS *

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I. INTRODUCTION

Chrysopidae is an important and well-defined family of Neuroptera. Both, during their larval and adult stages, Chrysopids feed upon the different stages of sucking insects, such as, *Bemisia tabaci* Genn., *Dialeurodes citri* R & H., *Diaphorina citri* Kuw., *Myzus persicae* Sulz., *Empoasca devastans* D., *Pyrilla perpusilla* W., *Drosicha stebbingi* Green, *Idiocerus atkinsoni* Leth., *Brevicoryne brassicae* (L.), *Rhopalosiphum pseudobrassicae* Dav., etc., thus keeping these destructive forms in check to some extent. The information about these Neuroptera in India is rather scattered and only very few species have been dealt with by workers in India. Lefroy (1909) gave, in broad outline, the characters of Chrysopinae. Husain and Trehan (1929) gave their observations on the population of *Chrysopa* sp. in cotton fields in the Punjab, made during their work on *Bemisia tabaci* (*gossypiperda*). Later Rahman (1940) studied briefly the life-history of *Chrysopa scelestes* Banks. Although the species is widely distributed, neither its biology nor that of any allied species in India has been studied thoroughly so far. It is, therefore, hoped that the detailed bionomics of *C. scelestes* described here will be useful to other workers.

* This work is a portion of the thesis submitted for the degree of Master of Science, in part fulfilment of the requirements of the University of the Punjab.

II. MATERIAL AND METHOD

The material used in these studies was chiefly obtained from cotton and cauliflower plants grown at the farms of the Agricultural College, Lyallpur. The adults are negatively heliotropic, and keep hiding themselves in dark and humid places during daytime, and fly about actively a little before sunset. Consequently, evening is the best time for collecting them with hand-nets. Very few of them can thus be caught between 9 A.M. and 3 P.M. Light traps were also tried to collect adults, but without much success.

Females collected from the field were put in glass tubes and were fed on honey and water or sugar solution or honey-dew put on cotton leaves. The larvae on hatching were transferred into separate tubes so as to prevent the stronger larvae feeding on weaker ones. In a single tube only 4-5 1st stage larvae or two 2nd or 3rd stage larvae were reared. During summer season the food was supplied on every 3rd day as the leaves dried up soon, while during winter it was changed after 5 or 6 days.

Adults in captivity always laid eggs during the night. Attempts were made to note the oviposition under different coloured lights but in vain. A few fertilised females were kept at night in a tube in strong electric light (100 Watts), but did not lay eggs. In the morning, the electric light was put out and as soon as there was a decrease in the intensity of light the females laid eggs and thus observations on egg-laying were recorded.

III. DESCRIPTION OF VARIOUS STAGES

(i) *Egg*.—The egg (Fig. 1) is oval in shape with a smooth chorion and is placed at the tip of a hair-like foot stalk (*P*), of transparent and gelatinous consistency. Micropylar apparatus (*m*) is saucer-shaped like a flattened knob with many striae radiating from the centre. Freshly laid eggs are greenish in colour and with maturity become grey. The segmentation of egg can be made out from red spots or streaks which appear within 36 hours. The ocelli appear as dirty red patches on sides within the next 24 hours. At this stage longitudinal depressions appear on sides and the tip of the mandibles can be seen near the mid-ventral line below the ocelli. A small red streak, the egg-burster (Fig. 10, *B*) becomes prominent just before hatching in between the mandibles (*Ma*). Red streaks across the egg mark the body segments. Abdominal segments are yellowish white; legs and warts translucent and the setae almost transparent. Average size of egg (mean of 20 eggs) is 0.8×0.36 mm. and that of the foot-stalk 2.6 mm. The egg-shell is pure white with a longitudinal rent near the micropylar end through which protrudes a portion of the embryonic moult (Fig. 17, *M*) with the egg-burster.

The egg-burster (Fig. 8) can be studied by picking out the moult from the rent of the egg-shell. It is a thick chitinous part of the embryonic moult, triangular in shape with a number of teeth (*T*) varying from 23-25, which give it a saw-like appearance. Size 0.12×0.07 mm.

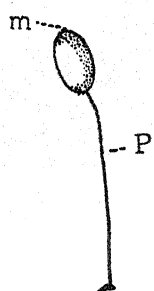


Fig. 1



Fig. 2



Fig. 3

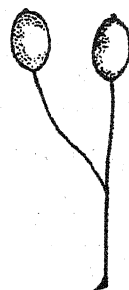


Fig. 4

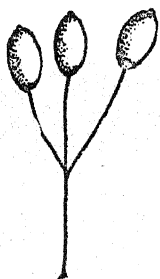


Fig. 5



Fig. 6

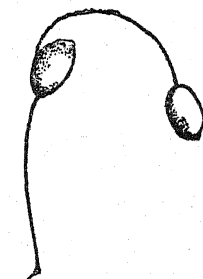


Fig. 7

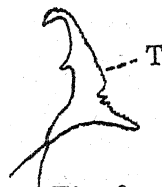


Fig. 8



Fig. 9

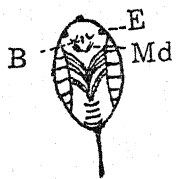


Fig. 10



Fig. 11



Fig. 12



Fig. 13

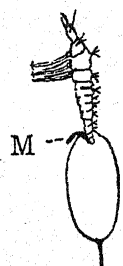


Fig. 14

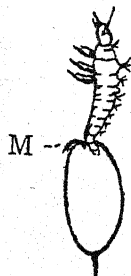


Fig. 15

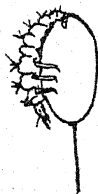


Fig. 16

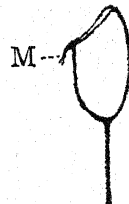


Fig. 17

Chrysopa scelestes Banks.

(ii) *Larva*.—Chrysopid larvae are compodeiform, with suctorial mouth-parts. The body is provided with setae arising from the dorsolateral tubercles. One-jointed tarsus having a trumpet-shaped empodium between the tarsal claws is present in all the instars.

1st and 2nd instar larvae appear to be dark reddish owing to the presence of streaks in each segment. Head is greenish yellow with two dark red lines arising from the bases of antennae and reaching the entire length of the head. Mandibles are black with red tips. Ocellar fields black in colour. Prothorax with one or two pairs of longitudinal black lines; meso- and meta-thorax each with two black patches. Abdominal segments with reddish black longitudinal lines.

In the 3rd stage larvae (Fig. 18), head is greenish with two black converging lines. Mandibles, palpi and antennae translucent, red at tips. Body colour light yellowish white. Prothorax with two pairs of black lines; meso- and meta-thorax with black dots, the area around the black dots reddish black. Abdominal segments with longitudinal red lines or transverse black lines. Some characters for distinguishing various instars are given below:—

Body Measurements

Instar		Body length in mm.	Width at meta- thorax in mm.	Width of head in mm.	Length of mandibles in mm.
1st Instar	..	2.29	0.47	0.340	0.32
2nd Instar	..	4.27	1.06	0.566	0.45
3rd Instar	..	6.57	1.70	0.798	0.71

Number of Setae

Instar		Thoracic segments			Abdominal segments						
		Pro-	Meso-	Meta-	2nd	3rd	4th	5th	6th	7th	8th
1st Instar	..	2	3	3	2	2	2	2	2	2	2
2nd Instar	..	7	8	8	7	7	7	7	7	7	6
3rd Instar	..	8	9	9	9	9	9	9	6	6	6

(iii) *Pupa*.—The cocoon (Fig. 19) is spherical and purely white in colour. It is thin but difficult to tear and in comparison to the size of the adult the size of the cocoon is very small, being only 2.3 mm. On the first and the second day after the spinning of cocoon, the larva is without setae (Fig. 20). On the second day it may develop small wing pads (Fig. 21, *W*). The larval skin becomes loose and on the third day the wing pads are fully developed, the larva pupates and throws

off the last larval moult. Wing tracheation appears on the fourth day (Fig. 22). The pupa is creamy in colour with two pairs of prominent wing pads (*W*). Eyes (*E*) are dirty yellow. Antennae (*A*) are white, curved over the eyes and passing over the thorax are finally curled in an 'S'-shaped loop partly over the wing pads and partly over the abdomen. The signs of sutures appear on the thorax on the fourth day; the latter is completely segmented on the fifth when the eyes also turn black. Black hairs appear on the sixth day on the antennae and wings; the eyes turn bright green.

(iv) *Adult*.—The general body colour is bright green with a white dorsal streak and appendages with wing veins similarly coloured; the eyes exhibit a metallic lustre. The antennae are delicate, filiform and longer than the body.

IV. LIFE-HISTORY (Appendix I)

1. *Adult*

Duration of adult stage.—Owing to high temperature in summer, adults died in the laboratory in 2–4 days, but when the temperature was cooled down by keeping the muslin (tied round the tubes) wet and when fed on honey and sugar solutions, they lived for 8–9 days. The adults on an average lived for 14–17 days in winter, the maximum period being 28 days during March. At 15° C., they lived for 65 days. The temperature of the laboratory during the course of these experiments is given in Appendix III. The pre-oviposition period was 3–7 days.

Food and activity of the adults.—The adults fed on various stages of Rhynchota, honey-dew, etc. They also fed voraciously on honey, sugar solution and plain water. They are poor fliers because of their comparatively heavy body. They locate their food with their sensitive palpi, eyes being of no use in this respect. The most peculiar habit is that of cleaning the antennae and pulvilli. The antennae are cleaned by the tarsi of fore-legs while the pulvilli are cleaned by the mandibles and maxillae.

Copulation in Chrysopidae was first described by Smith (1922). It has been observed several times during this investigation. Before copulation males and females jerk their abdomens, twist them and rub their antennae. They move together, stop; and the male twists its abdomen under that of the female and the tips of the male and female abdomens unite (Fig. 25). This continues for eleven minutes. The female begins to move its abdomen and antennae. At last it becomes restless and separates after nine minutes. They both try to bite or lick their genitalia.

Oviposition has been observed and described in various species by several writers, notably Fitch (1855), Muller (1872–73), Vines (1895), Girault (1907) and Smith (1917–22).

In *C. scelestes*, the eggs are laid the night following copulation. A female about to lay eggs, moves its abdomen and antennae. Rings of contractions run

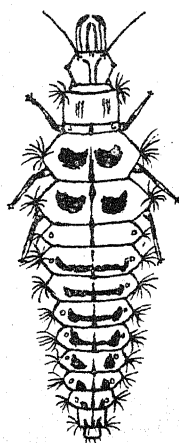


Fig. 18

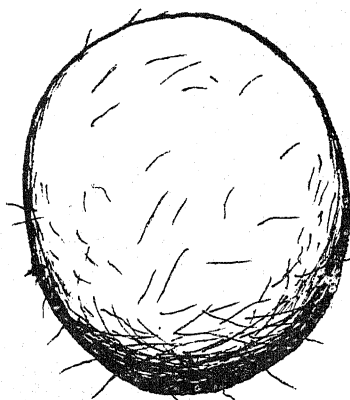


Fig. 19

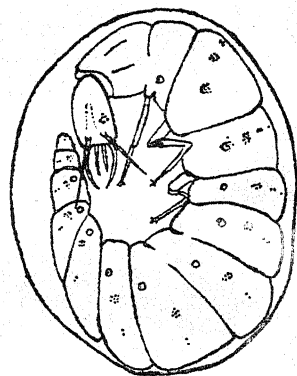


Fig. 20

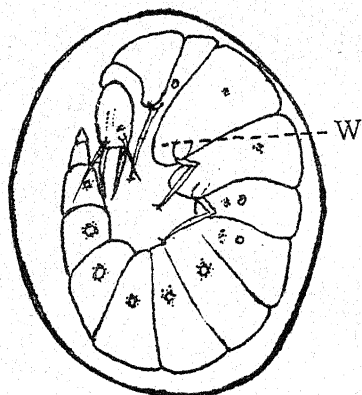


Fig. 21

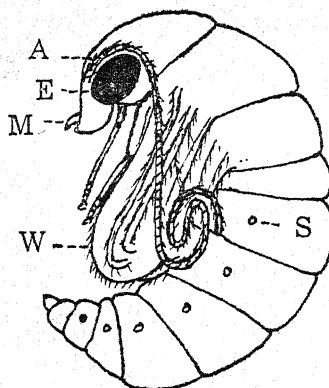


Fig. 22

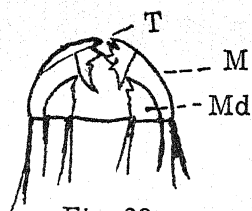


Fig. 23

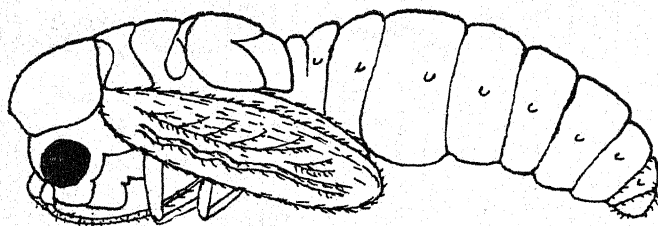


Fig. 24

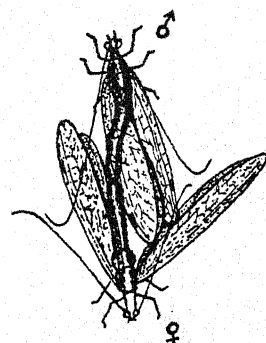


Fig. 25

Chrysopa scelestes Banks.

to the tip of the abdomen. Vulva is swollen and finally bulged out. The female brings the tip of her abdomen near substratum, secretes a gelatinous transparent drop of liquid, raises the abdomen thereby pulling out a uniform gelatinous thread. It takes 5-7 seconds to perform the above action. Then the micropylar end of the egg appears. It attaches the egg to the stalk, holds it for some time to let the thread harden. The genitalia are withdrawn with a jerk, after 10-30 seconds, leaving the egg behind.

Abnormalities in oviposition.—Eggs are laid singly (Fig. 1) but abnormalities (Figs. 2-7) appear when a female is made to oviposit in captivity. Smith (1922) described in detail such abnormalities in *Chrysopa nigricornis* and *C. oculata*. Besides those mentioned by Smith (1922), two more abnormalities were observed in *C. scelestes*. In hot summer, egg-less stalks (Fig. 6) are laid, while in cold winter stalk-less eggs are deposited (Fig. 2) as the peduncle does not harden due to low temperature.

Location of eggs and fecundity of female.—The eggs are deposited on any part of the plant, viz., stem, leaves, flowers, petioles, etc., but generally they are found in the vicinity of food. If a female is attracted to light, she may lay eggs even on the lamp or any other object lying nearby. The average number of eggs laid in captivity was 65, but as many as 127 eggs may be laid (Appendix II).

Duration of egg stage.—The eggs were mostly laid during the night and hatched during the daytime. In summer the egg stage lasts for $2\frac{1}{2}$ - $3\frac{1}{2}$ days and even $4\frac{1}{2}$ days during the rainy season, while in winter it may be as long as 15 days (Appendix I).

Hatching.—Hatching of *C. scelestes* eggs was studied a number of times during summer. The embryo is clearly visible owing to transparency of the chorion and before hatching lies with its head and tip of abdomen bent ventrad with the result that mouth-parts and antennae are stretched towards the micropylar end. The ocelli are prominent and visible to the naked eye. On the mid-ventral line of egg, in between the eyes, there can be seen a short highly chitinised red line, the egg breaker. Just before hatching, the chorion of the sides and the two poles of the egg get pressed together inside so as to exert pressure on the egg-burster. The fore-part of the body becomes turgid, especially labrum-clypeus, due to rush of blood and results in the piercing of the egg-breaker into the amnion and then the chorion. The signs of hatching are the peristaltic movements of the larva and the presence of air bubbles, around the egg-breaker. The egg-burster is pushed through up to its entire length and the dorsum of head comes out in about 2 minutes with the rupturing of the pre-larval skin. Soon after the chorion ruptures towards the micropyle owing to contractions and expansions and the fore-part of the thorax is forced out in about 200 seconds. The larva makes a halt at this point (Fig. 11). The labrum-clypeus is still turgid and pulsates. After a lapse of a short interval of rest, the prothorax is forced out in 230 seconds and the turgidity of the head decreases. In the meanwhile the thorax and the abdomen

emerge (Fig. 12), the setae springing up to their normal position, and the larva arches over the egg-shell with the tips of mouth-parts, antennae, legs and the abdomen inside the shell (Fig. 13). This takes place about 300 seconds from the start of the hatching. In the next few minutes the mouth-parts, the antennae and the legs are withdrawn leaving the egg-burster and the prelarval skin behind; the larva stands out erect on the tip of the abdomen with the legs and mouth-parts fully expanded (Fig. 14). The larva moves the legs making them free and in this performance the chitin hardens. The mandibles are transparent white, red at tips, the maxillae lie parallel to them and are somewhat blunt and colourless. Labial palpi adhere to the mandibles and there is no mouth opening. After 8-10 minutes from the start of hatching, the larva bends the posterior part of its abdomen (Fig. 15), and remains clinging to the egg-shell, for 50-100 seconds, holding it with its legs, with the tip of the abdomen still inside the egg-shell (Fig. 16). After some time, *i.e.*, 20-23 minutes or so, when the larva feels hungry, it withdraws the tip from the egg-shell to descend in search of food and moves it in a characteristic manner as if it were cleaning its body.

Duration of larval stages.—The eggs hatched out in the morning and pupation generally took place in the afternoon. A larva took 6-9 days to become fullfed for spinning during summer. It remains in the cocoon as larva for 2 days and then pupates. In the winter, the larval stage may last a month or so. There are three larval instars, the 1st lasts 1-4 days in summer and 8-13 days in winter, the 2nd 1-3 days in summer and 6-12 days in winter, while the 3rd up to the spinning of cocoon occupies 2-3 days in summer and 11-23 days in winter (Appendix I).

Descent from the egg-shell.—Just after hatching the larva holds the egg-shell with its legs, the tip of abdomen being inside the shell for some time; the head of the larva points to the anti-micropylar end of the stalk. When the tip of the abdomen is taken out, the larva comes down with the help of its claws and tail end and immediately begins to search for food. If no food is available, the larva starves to death within a day. It feeds on eggs and other stages of soft-bodied insects, *e.g.*, white-fly, aphid, etc. The larva is cannibalistic in nature.

Moultings.—There are four moultings in *C. scelestes* as in other chrysopids during the larval period. The 1st moult is the embryonic one, the 2nd and the 3rd are cast during the larval period and the 4th moult is shed while the larva is inside the cocoon.

The 1st moult is very quick and hence difficult to observe. It begins when the head of the emerging larva is out of the rent of the egg. The moult is left along with the burster inside the egg-shell.

The 2nd and the 3rd moults can be easily observed because the process can be seen while moulting is in progress. Setae of the prothoracic segment are folded ventrad and caudad forming a semicircle round the prothorax. The rest of the setae are folded across the dorsum. The old setae become somewhat shrivelled.

Prior to moulting the larva is inactive and less sensitive to touch. The anal end gives out a copious secretion. The pulvilli do not function well. Just before moulting, the larva secretes a drop of gelatinous fluid to attach the tail to the object on which it rests. It begins to twist and pulls itself. The contraction of the body segments is from the posterior to the anterior. This continues for some time and then the abdomen is seen freeing itself of the moult skin. The body is pulled forward and the pressure is highest at the prothorax, which begins to split at the mid-dorsal line. The split increases in size. The thorax arches, the head bends ventrad and the abdomen is pulled forward. In the meantime the mouth-parts are carefully withdrawn. Head is lifted slowly with the arching of the thorax. During this process the legs are drawn; tracheae are pulled out as hollow threads. When the jaws and the antennae are out, the legs are pulled out, the metathoracic legs being the last to get free. By this time the abdomen is free and setae are in their natural condition as the old skin is left behind. Newly moulted larva is translucent. It cannot use its legs and mandibles as the chitin is soft. The body markings are retained in the moult.

The 4th or the final moult takes place in the cocoon, hence it is difficult to observe it. A black disc on one side of the cocoon shows that the larva has moulted into pupa. It is nothing but the last larval skin pushed off to the end of the abdomen. The moulting can be studied in exceptional cases where the larva fails to spin the cocoon, when disturbed at the time of spinning. The skin splits over the thorax. The larva moves its head up and down, slipping the skin slowly back. Then it moves the thorax and the abdomen to slip the moult finally to the tip of the abdomen.

Habits and activity of the larva.—It is very difficult for an untrained eye to find out the larvae owing to the body contents shining through and their active movements. The larva can be collected only from leaves heavily infested with white-fly.

Food and feeding method.—When a larva is hungry it moves about quickly in search of food and may overlook a number of white-flies in haste. It destroys its victims like the starling, *i.e.*, it may feed on a few but kills many. At the time of feeding the larva may insert only one or both the jaws. If one mandible is inserted into the victim, the other is used to hold the victim. The jaws are not applied alternately but the one which pierces first is used for sucking. As the sucking proceeds, the maxilla starts sliding forward and backward to help in easy flow of the body juice and may grind any bigger particle that happens to come in the groove. Air bubbles may also come in as the maxilla slides. In the case of white-fly nymphs sticking to the leaf, the jaw is pierced from underneath. It is slowly pushed inside as the juice is being sucked. If the body juice is unpalatable, the larva leaves the victim and tries another, but in case it is to its taste even the little quantity sticking to the periphery of the nymphs is sucked thoroughly.

Another curious habit of the larva is that when it is hungry it may suck the whole of the body juice but later on as the intensity of hunger diminishes, the larva takes to puncturing the victim, sucks a little quantity of juice and tries another. The adult hosts having wings, *e.g.*, citrus psylla are attacked on the ventral side of the abdomen and sucked with the strong jaws to dryness. Aphids and jassids are generally attacked on the abdomen. *Drosicha stebbingi* is attacked only when it is in a state of moulting. A yellowish fluid comes out from the punctured portion of the body which dries up soon. The death of the mealy bug is due to decreased vitality and injection of some poisonous secretion. Another curious habit of the larva is that if a large number of them are left on cotton leaf infested with white-fly nymphs, the result will be that the larvae will not suck all the host nymphs present on the leaf though the amount of food may be far less than what will be actually required to satisfy the larvae. This may be due to the difficulty in locating the smaller number of the host nymphs over a comparatively larger area. It has been observed that the larvae locate their food with the help of sensory hairs at the tip of the maxillae.

Larval excreta.—They are of two kinds: (1) Clear gelatinous fluid secreted through the anal tip for purposes of attachment while moulting or moving or spinning cocoon. (2) Black coloured excrement retained in the mid-intestine, as the intestine is closed posteriorly. The latter is small in quantity because only liquid and digested food is taken in by the larvae. It is voided just after the emergence of the adult.

Duration of the pupal stage.—It is difficult to give the exact duration of the pupal stage because the last larval moult cannot be observed on account of the opaqueness of the cocoon. The pupal stage proper in summer is about two days shorter than the duration of the period between the spinning of the cocoon and the emergence of the imago. The pupal stage combined with the prepupal stage inside the cocoon, lasts a month in winter and 6–8 days in summer (Appendix I).

Location.—In cotton fields the larva spins its cocoon on the stem, petiole, underside of the leaf, between the folds and the ribs of leaf. On big trees, it pupates under rough bark, while in berseem fields it has been observed pupating among aphid skins.

Spinning of the cocoon.—A full grown larva stops feeding before pupation. It becomes somewhat sluggish and moves about in search of a suitable place. It lies on its back or on its side with the head drawn to the ventral side and starts spinning with the tip of its abdomen (the tenth segment) from which issues a transparent gelatinous silky secretion. First an attachment disc is formed, and the tip of the abdomen is moved to another place and a thread is issued as it moves. This process goes on till a foundation is formed. The larva shifts on to the foundation holding the thread with its legs and again starts spinning. The spinning is in a triangular fashion. The larva shifts occasionally to new positions to make the wall of the cocoon, which affords rigidity. At

this stage the larva is without setae. As the triangle becomes smaller, the larva becomes slower and is partly hidden by the wall of the cocoon. Final spinning is confined to the plastering of the cocoon which completely hides the larva from sight. If the larva is disturbed at the time of spinning, it either moves off and lays the foundation of another cocoon, or fails to spin and passes to the pupal stage without the cocoon. The average time record for spinning the foundation was 26 minutes and for complete spinning 1 hour and 55 minutes.

Condition of the larva and the pupa in the cocoon (Fig. 20).—The larva remains in the cocoon in the larval condition for a few days. The head and the tip of the abdomen are bent ventrally so that the ends of the mandibles and a part of the dorsal portion of the head are hidden underneath the tip of the abdomen. The body is without setae. It changes its position in the cocoon off and on, when it feels uncomfortable. A black patch may be found appearing within a few days after spinning, and represents the last larval moult when changing into pupa. In the early parts of the pupal life, the cocoon appears light yellowish white but changes to green one or two days before the emergence of the imago.

Emergence of pupa.—The pupa comes out of the cocoon through a circular hole made opposite to the black patch. Previous workers believed that either a circular lid is spun in the cocoon which is knocked off or a disc is cut with the help of the pupal mandibles, which have also been confirmed by these two observations:—

1. If a cocoon in which the pupa is dead and shrivelled or alive is pressed a little, a circular lid is automatically knocked off, proving thereby that an upward pressure of the pupa helps in knocking off a lid which might have been spun at the time of construction of the cocoon.

2. In some cocoons, from which pupae had emerged, an actual spiral cut could be seen, proving that the pupal mandibles do cut open the cocoon.

It may be said that nature has supplied two structures to the pupa for its escape from the cocoon. If one fails to serve the purpose, the other may be used.

Pupal moult.—After emergence from the cocoon, the pupa settles down on a suitable place for moulting and expands its body to normal adult size. It raises and lowers its abdomen and also the head. The abdomen and the thorax are drawn forward leaving the pupal moult behind. The pressure on account of stretching and expansion causes a rent near the junction of the prothorax and the head which extends backward by the body movements. The imago first draws out the mouth-parts bending the head. Then it draws out the antennae and prolegs; and afterwards the mesolegs and the wing pads are pulled out. As the imago lifts itself, the tracheal tubes are shed. The imago moves out with the help of two pairs of legs to free the metathoracic legs and finally the abdomen leaving a hyaline skin behind, with a rent on the dorsal side. Time record for moulting:—suitable place 13 minutes; rent 12 minutes; complete moulting 18 minutes.

Adult soon after emergence.—Just after throwing off its pupal skin, the imago (Fig. 24) moves about a little and tries to spread its wings after coming to rest. The expansion of the wings starts at the bases and proceeds outward. The wing expansion is complete in 20 minutes. When the adult has gained its normal size and condition, it voids a black mass consisting of the larval excreta.

V. SEASONAL HISTORY

The laying of eggs in batches results in an overlapping of generations which is no doubt useful in that all the stages of the host are attacked and killed throughout the season. In the laboratory, adults died after completing 2-3 generations. In the heat of summer death may result even before copulation, whereas in winter they sometime fail to copulate in captivity. The life-cycle varies considerably with the season. It may be completed in 16-17 days in summer, while it may take 30-45 days in winter. Hence we may conclude from the life-history that there may be 10-12 generations in a year.

September, October, March and April are the best months for the development of *C. scelestes* when the temperature varies from 72° F. to 99° F. and the relative humidity from 67 to 87 per cent.

VI. SUMMARY

The bionomics and life-history of *Chrysopa scelestes* Banks, an important predator of *Bemisia tabaci* G. (*gossypiperda* M. and L.), have been studied.

The number of eggs laid during the life of a female varied from 47 to 127. Under laboratory conditions the eggs hatched in 2½ to 4½ days in summer and 12 to 15 days in winter. The larval and the pupal stages lasted for 6 to 9 days in summer and 12 to 38 days in winter respectively. There are three larval instars. The adults died within 5 days in summer but lived on for 2½ months in winter. There may be 10 to 12 generations of the insect in a year.

VII. ACKNOWLEDGMENTS

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EXPLANATION OF FIGURES

Chrysopa scelestes Banks

- FIG. 1. Normal egg. *m*, micropyle; *P*, peduncle.
- FIGS. 2-7. Abnormal eggs.
- FIG. 8. Egg-breaker. *T*, teeth.
- FIG. 9. Freshly laid egg.
- FIG. 10. Fully matured egg (ventral view). *B*, egg-breaker; *E*, ocelli; *Md*, mandible.
- FIGS. 11-16. Different stages in the process of hatching. *M*, 1st larval moult.
- FIG. 17. Egg-shell. *M*, 1st larval moult.
- FIG. 18. Third instar larva (dorsal view).
- FIG. 19. Cocoon.
- FIG. 20. Condition of larva in the cocoon.
- FIG. 21. Condition of larva in the cocoon. *W*, wing pad.
- FIG. 22. Pupa, *A*, antenna; *E*, eye; *W*, wing-pad; *S*, spiracle; *M*, pupal mandible.
- FIG. 23. Pupal mandibles. *M*, pupal mandible; *T*, teeth; *Md*, adult's mandible.
- FIG. 24. Imago.
- FIG. 25. Copulation.

APPENDIX I

Dates and durations of various events and instars in the life-history of *C. sclectes*

Dates of oviposition, 1939-40	Dates of hatching	Duration of egg stage in days	Date of 1st moulting	Duration of 1st instar in days	Date of 2nd moulting	Duration of 2nd instar in days	Date of spinning cocoon	Duration of cocoon in days	Duration of larval stage in days	Emergence of imago	Duration of cocoon stage in days	Date of oviposition	Preoviposition period in days	Died on	Duration of adult stage in days
2-8-39	4-8-39	21	9-8-39	2	..	..	9-8-39	..	6	16-8-39	7	..	..	..	..
5-8-39	7-8-39	21	..	..	..	..	14-8-39	7	7	22-8-39	8	..	..	..	..
23-8-39	25-8-39	21	..	..	..	..	1-9-39	7	7	7-9-39	6	..	..	..	..
10-8-39	12-8-39	21	13-8-39	1	15-8-39	2	19-8-39	4	8	26-8-39	7	..	..	28-8-39	2
10-8-39	13-8-39	31	14-8-39	1	16-8-39	2	19-8-39	3	7	26-8-39	7	..	..	27-8-39	1
1-9-39	4-9-39	31	..	..	..	..	10-9-39	7	7	18-9-39	8	..	..	..	..
8-9-39	10-9-39	21	..	..	..	..	16-9-39	..	7	23-9-39	7	..	..	..	..
13-10-39	15-10-39	21	18-10-39	3	21-10-39	3	23-10-39	2	9	29-10-39	6	..	..	..	..
12-10-39	15-10-39	31	19-10-39	4	..	..	23-10-39	9	9	1-11-39	9	..	..	..	..
13-10-39	15-10-39	21	..	..	..	..	23-10-39	..	9	1-11-39	9	..	..	..	..
15-10-39	17-10-39	21	..	..	..	..	27-10-39	11	11	6-11-39	10	..	..	..	..
14-10-39	16-10-39	21	..	..	..	..	23-10-39	..	8	1-11-39	9	..	..	..	..
17-10-39	19-10-39	21	..	..	..	..	29-10-39	..	11	4-11-39	6	13-11-39	3	18-11-39	8
19-10-39	21-10-39	21	4-10-39	6	..	..	1-11-39	..	12	12-11-39	9	17-11-39	5	25-11-39	65
29-10-39	1-11-39	31	..	..	..	..	12-11-39	..	12	26-11-39	11	..	..	..	13
5-11-39	10-11-39	51	13-11-39	3	..	..	27-11-39	..	18	9-12-39	12	..	..	..	..
12-12-39	14-12-39	121	..	..	3-1-40	..	18-1-40	15	26	22-2-40	35	28-2-40	6	10-3-40	17
4-12-39	19-12-39	151	..	..	..	..	16-1-40	..	28	16-2-40	31	..	..	..	..
19-12-39	1-1-40	131	12-1-40	11	17-1-40	5	31-1-40	14	31	27-2-40	27	..	..	..	..
14-12-39	25-12-40	111	3-1-40	9	12-1-40	9	31-1-40	19	38	27-2-40	27	..	..	..	..
15-12-39	27-12-40	12	4-1-40	8	10-1-40	6	25-1-40	15	30	26-2-40	33	..	..	..	..
4-1-40	18-1-40	141	31-3-40	13	12-2-40	12	22-2-40	10	35	8-3-40	15	..	..	5-4-40	28
6-1-40	19-1-40	131	..	..	..	..	..	..	..	..	..	..	..	..	..
15-2-40	21-2-40	51	..	..	..	..	6-3-40	..	16	22-3-40	16	..	..	..	..
16-3-40	21-3-40	61	..	..	..	..	..	..	..	..	..	..	..	..	..
19-3-40	25-3-40	61	..	..	..	..	6-4-40	..	17	12-4-40	6	..	..	..	..
20-3-40	25-3-40	51	..	..	..	..	7-4-40	..	13	13-6-40	7	..	..	..	..
21-3-40	26-3-40	51	..	..	..	..	8-4-40	..	14	14-1-40	7	..	..	..	..
18-3-40	23-3-40	51	..	..	..	..	4-4-40	..	14	16-4-40	8	..	..	..	..
15-4-40	18-4-40	31	23-4-40	5	26-4-40	3	29-4-40	3	11	12-4-40	8	..	..	..	..
11-5-40	14-5-40	21	..	..	..	..	15-5-40	..	9	7-5-40	8	..	..	..	..
12-5-40	14-5-40	31	..	..	..	..	22-5-40	..	..	21-5-40	6	..	..	..	..
29-5-40	30-5-40	21	3-6-40	4	..	..	..	..	..	29-5-40	7	..	..	..	..
12-6-40	15-6-40	31	..	..	..	..	8-6-40	..	9	16-6-40	8	..	..	..	..
23-6-40	27-6-40	41	..	..	..	..	23-6-40	..	..	30-6-40	7	..	..	..	..
24-6-40	28-6-40	41	..	..	..	..	4-6-40	..	8	12-6-40	8	..	..	..	..
3-7-40	6-7-40	31	..	..	..	..	15-6-40	..	..	22-7-40	7	..	..	..	..
14-7-40	16-7-40	21	19-7-40	3	20-7-40	1	23-7-40	3	10	31-7-40	8	7-8-40	7	12-8-40	12
29-7-40	31-7-40	21	3-8-40	3	4-8-40	1	6-8-40	3	8	13-8-40	7	..	..	..	..
7-8-40	9-8-40	21	11-8-40	2	12-8-40	1	15-8-40	3	7	21-8-40	6	..	..	..	..

APPENDIX II

Fecundity record of *C. scelestes*

Emergence of adult on	Oviposition started on	Days and No. of eggs										Total No. of eggs
		1st	2nd	3rd	4th	6th	10th	12th	22nd	27th	29th day	
8-11-39	13-11-39	5	13	12	10	18	4	18	34	2	11 eggs	127
10-11-39	13-11-39	5	13	12	28	..	..	..	..	..	..	58
10-11-39	13-11-39	8	22	11	..	..	..	..	..	..	..	41
12-11-39	17-11-39	1st	2nd	3rd	4th	5th	6th	7th	8th day			
		8	14	10	32	..	6	..	2	..	eggs	72
12-11-39	17-11-39	6	14	9	18	4	9	6	..	..	..	66
		1	2	3	4	5	6	7	8	9	10 ..	
22-2-39	28-2-39	6	..	28	12	3	2	..	..	5	4 ..	60
22-2-39	28-2-39	6	..	14	15	6	..	4	6	..	..	51
22-2-39	28-2-39	7	..	31	10	6	..	..	..	..	..	54
31-7-40	5-8-40	1st	4th	5th	6th	7th	8th	9th day				
		21	14	10	11	6	10	6	..	..	eggs	78
31-7-40	5-8-40	..	..	..	10	17	12	6	..	..	..	45

Eggs laid per female.....65

Oviposition record kept for ten females gave 41 minimum and 127 maximum number of eggs per female.

APPENDIX III

Temperature record (laboratory) in degrees Fahrenheit

		June, 1939	July, 1939	August, 1939	September, 1939	October, 1939	November, 1939	December, 1939	January, 1940	February, 1940	March, 1940	April, 1940	May, 1940	June, 1940	July, 1940	August 1940
Maximum	..	100	100	95	102	102	89	68	68	78	79	94	101	102	100	95
Minimum	..	88	86	86	75	70	59	58	43	51	54	54	83	86	87	81

NEWS AND ANNOUNCEMENTS

The Food and Agricultural Organization of the U.N.O. convened an International Meeting on infestation of foodstuffs in London from the 5th to the 12th August 1947. Twenty-seven countries were represented and in all there were 51 delegates and two observers. Dr. H. S. Pruthi, Plant Protection Adviser to the Government of India, Ministry of Agriculture (Leader) and Mr. K. R. Sontakay, Director of Storage, Ministry of Food, represented India at the Conference.

In opening the Conference Sir John Boyd Orr, Director General of the F.A.O., said, that the state in which Europe had been left by the war demanded urgent attention, but in Asia many millions of people are perennially as ill-fed as the most desperate victims of the war. It was emphasized by him that on account of the increase of world population world food production would need to be doubled in the next 25 years so that everybody is provided with adequate diet in order to maintain health and working efficiency. It was further stressed that the Conference should recommend such measures as can be immediately taken up with the existing knowledge although further research may continue. The Conference discussed the following subjects:—

- I. Appraisal of food losses in different parts of the world.
- II. World channels of infestation and dissemination and consideration of methods and standards of inspection.
- III. Insect and mite pests and methods for their control.
- IV. Rodents and their control.
- V. Mould and fungi in grain stores.
- VI. Grain drying.
- VII. Dissemination of knowledge and collective measures against infestation in storage.
- VIII. Modern construction of storage places.
- IX. Supply position of insecticides, raticides and fungicides.
- X. Research.

From the statement of the extent of losses during storage, as prepared by the F.A.O. on the basis of the reports received from various nations, it was decided that an over-all loss due to insects, rodents and moulds could be reckoned at 10%. The loss shown against India, *i.e.*, 5% based on the note sent by the Plant Protection Adviser to the F.A.O. was considered quite reasonable, if not conservative. The Conference, however, felt that 10% loss was an under-estimate of the actual position, as infestation is comparatively higher in tropical and sub-tropical countries on account of the specially favourable climatic conditions for the development of insect pests, the large amount of grain retained by villagers and the storage and transport difficulties.

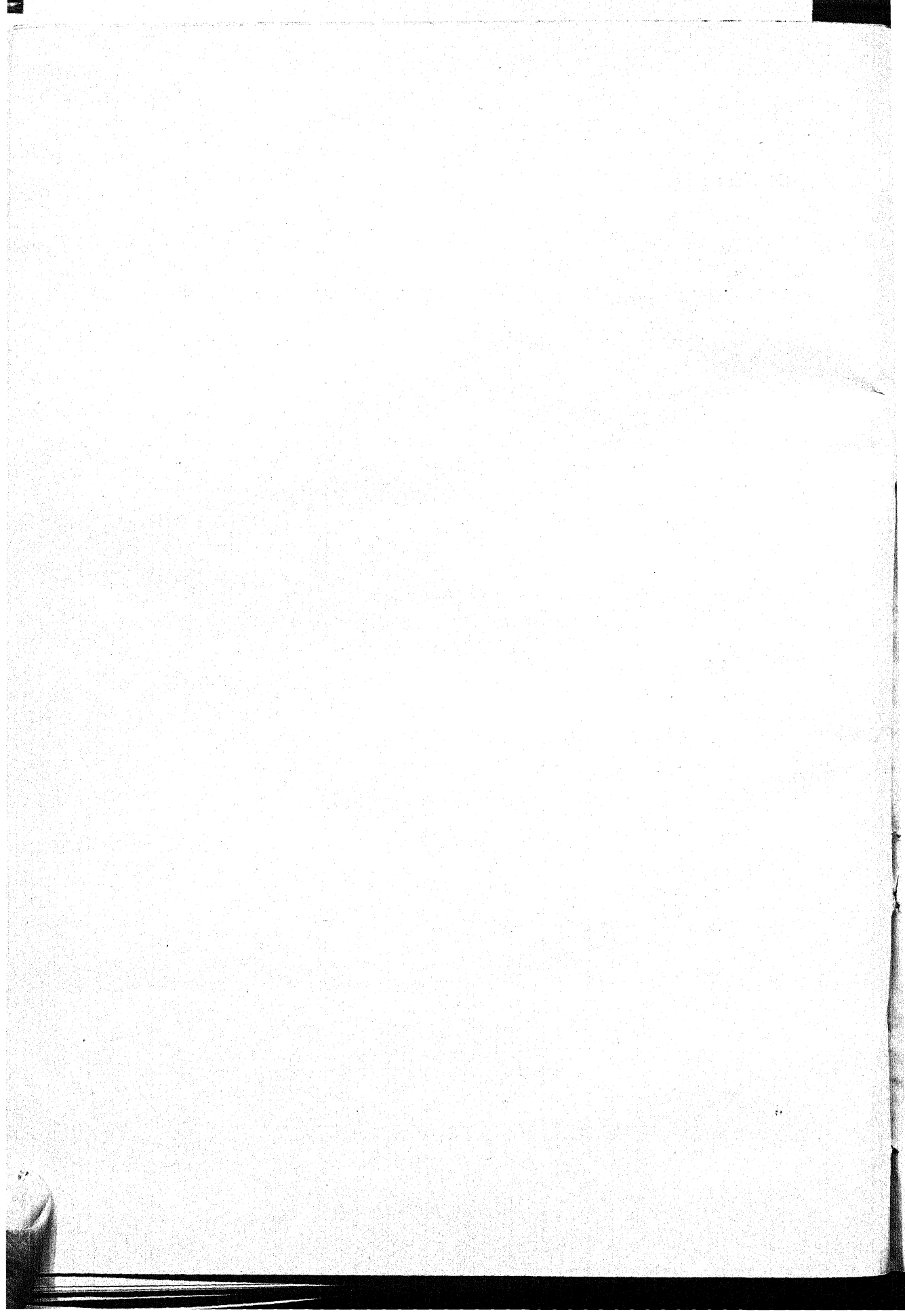
As a result of the deliberations extending over one week, the meeting unanimously recommended that:—

- (1) All member States should accept the principle that efficient prevention and control of food infestation is essential to the conservation of the world food supply.
- (2) All member States should maintain, or establish adequate organizations for the prevention and control of infestation at all stages from the farm to the consumer, with special emphasis on storage, processing and transport.
- (3) Special consideration should be given by all Member States to the provision and training of necessary technical personnel. Until more adequate staff is available, progress will inevitably be slow.
- (4) That the utmost use should be made of the various forms of publicity so that producers, handlers, processors and consumers may be informed about the proper care of food.
- (5) That member States should collect information on the losses due to infestation and make the information available to F.A.O.
- (6) That the F.A.O. should ensure that an appropriate information service is available to member States, and F.A.O. should co-operate with such established institutions as those administered by the Council of the Imperial Agricultural Bureaux, notably the Imperial Bureau of Entomology and the Imperial Bureau of Mycology.
- (7) That F.A.O. should endeavour to arrange the loan of experts as between member States for assistance in special problems.
- (8) That F.A.O. should arrange periodic Conferences of experts, both on a world-wide and a regional basis, such as is already operating in Europe, for joint discussions and exchange of experience and knowledge.

On the basis of these recommendations the following action was proposed to be taken in India:—

- (1) Estimates of losses due to infestation should be expressed in numerical terms such as weight or other economic terms. To this end, the use of "carbon dioxide production test" should be resorted to and more specific information regarding damage due to insects, rats and moulds and also due to bad handling of food grains at various stages should be collected. A definite basis on which the losses should be calculated should be furnished to the Provinces and States in the country.
- (2) More attention should be paid to the inspection of foodgrains imported from abroad; their condition of infestation and of the ships in which they are brought should be thoroughly investigated everytime a consignment arrives.

- (3) The question, whether DDT and Gammexane should continue to be used in India for the disinfestation of empty stores and for the dusting of the bags, should be examined more thoroughly in view of the opinion given by Dr. Galley of the United Kingdom that toxicologists had not agreed that there was no danger in the use of these chemicals.
- (4) More attention should be paid to the work of rat-control and rat-proofing of godowns.
- (5) Steps should be taken to continue the improvement recently effected by building overground *Khattis* of cement concrete or brick masonry with damp proof cement lining.
- (6) Greater publicity and education on storage should be carried out through films, broadcast talks, etc., so that producers, handlers, processors and also consumers should be fully conversant with the necessity of avoiding loss of valuable food and also with the dangers of consuming infected food. It is important that there should be an organization for assisting the farmer in his storage problems; this step will of course have to be taken by the Provincial Governments.
- (7) The necessity for setting up a Pest Infestation Laboratory should be examined, if proper research on grain fumigants cannot be carried out satisfactorily at any of the existing laboratories under the Indian Council of Agricultural Research and Indian Agricultural Research Institute.
- (8) Special consideration should be given to the provision and training of the requisite technical personnel.



PROCEEDINGS OF THE ENTOMOLOGICAL
SOCIETY OF INDIA, 1947

Delhi Branch—New Delhi

21st July

Communications—

The stages of the development of type (A) of tobacco curl.—C. K. Samuel.
A note on the control of mosquitoes and flies at the Indian Agricultural
Research Institute, New Delhi.—Rattan Lal.

United Provinces Branch—Kanpur

21st September

Communications—

Some observations on *Opius fletcheri* Silv., a parasite of *Dacus cucurbitæ* Coq.
—K. M. Gupta.
Parthenogenesis in the mustard sawfly, *Athalia proxima* Klug.—R. M. Verma.
Some observations on the ber fruit fly, *Carpomyia vesuviana* Costa.
—R. N. Singh.

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14. The Director of Agriculture, Hyderabad State, Hyderabad (Deccan).
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28. The Entomologist to the Government, C.P., Agricultural College, Nagpur.
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49. The Secretary, Indian Council of Agricultural Research, New Delhi.
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